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Roadway and Track

By

W. F. RENCH

AUTHOR OF "SIMPLIFIED CURVE AND SWITCH WORK"
FORMERLY SUPERVISOR ON PENNSYLVANIA RAILROAD

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To

MR. SAMUEL O. DUNN

EDITOR OF THE "RAILWAY AGE,"

WHOSE HIGH IDEALS IN RAILROADING

HAVE BEEN AN INSPIRATION EVERYWHERE,

THIS BOOK IS

RESPECTFULLY INSCRIBED

BY THE AUTHOR

The Section Headquarters

PREFACE

To the theme of this book might have been added a notation to the effect that the practice described is, in a large measure, that of the Pennsylvania Railroad, stated, of course, as the author conceives it. He has been constrained to adhere somewhat closely to those standards, because the whole of his 25 years' railroad service was spent in the engineering and maintenance departments of that road. As will be noted, however, methods are described in a number of places which are employed only experimentally on the Pennsylvania, but which have been accepted as standard on other roads. This has seemed proper in order that the book may be broadened beyond the scope of the practice of a single railway system.

In the past 50 years, standards have been changing continually as increasing demands were made upon the track structure. The changes have been mainly in ten-year periods: the 60-lb. rail of 1865, the 70-lb. rail of 1875, the 85-lb. rail of 1885, the 100-lb. rail of 1895, the P. S. sections of 1905, and the 130-lb. rail of 1915. Similarly, the 8-in. depth of ballast was standard as late as 1895, and the 18-in. depth until 1905, while the present common use is of 24-in. depth. At first 12 ties were used under the rail, then 14, then 16, then 18, now almost everywhere 20 are laid in main lines. The author well remembers the advent of the 100-per cent splice in 1895, the first important departure from plain angle bar design. The increasing use of tie plates and other track accessories has kept even pace with the passing of the years.

Some of the larger questions have not in the past been given the attention they deserve. Vegetation for banks, drainage, legal technology, a program of work, detailed methods, use of tools, labor saving devices; all these form important items in the general subject of maintaining track and roadway. Old methods of work, however efficient in the days of native labor, moderate speed and light traffic, must now give way to the newer practices in maintenance, de-

veloped by the ever-increasing burden of transportation and the public's insistent demand for the best.

Many books deal with these subjects in a wealth of detail; but the practical man has neither the time nor the inclination to analyze the various processes. Rules must be stated that, within the compass of a sentence, contain the meat of the practice recommended. Theorizing must be left to other treatises and only the hard facts and conclusions presented. Even detail must be curtailed that no undue demands may be made upon the limited time of the practical man. While the sentences are short, no effort has been made to simplify greatly the composition. It is believed that the principal excuse for any book is that the author has something to tell. His only duty then is to convey it in as pleasing and attractive style as possible.

No space is given the important subject of curves and switches because the author has covered them in another work. Problems in construction have likewise been avoided, and the scope of the work confined entirely to maintenance practice.

The thanks of the author are due the management of the Pennsylvania Railroad for uniform consideration shown him as an employee, and especially for the privilege of making free use, in a number of instances, of the excellent language in which the maintenance rules of the road are written. Acknowledgment is likewise due the author's friend and adviser, Mr. E. T. Howson, Western editor of the "Railway Age" and editor of the "Railway Maintenance Engineer," for assistance given in the preparation of the manuscript. His suggestions throughout the work have been many and valuable.

Table of Contents

PART I—ROADWAY

CHAPTER I

THE ESSENTIAL ELEMENTS IN ROADWAY MAINTENANCE

1 A SUMMARY OF THE MORE IMPORTANT POINTS 23
Scope of Roadway Work—Legal Protection, Vegetation, Drainage—Drainage Most Essential—Subsidiary Items—Policing Justified—Protection of Title—Labor-Saving Methods—Use of Tools—Program of Work.

CHAPTER II

THE RIGHT OF WAY

2 GENERAL PRINCIPLES 27
Definition of Right of Way—Custodians of the Property—Adverse User and Adverse Possession Defined—Difference in Rule for Individual and Company.

3 LEGAL PRINCIPLES AFFECTING RIGHT OF WAY 28
Lines Referred to Tracks or Streams—Eminent Domain Limited to Land—Restrictions Removed by Purchase—Setting Back Water Lines—Relation to Highways—Fencing the Right of Way—Trees Overhanging the Right of Way.

4 THE EFFECT OF ENCROACHMENTS 31
Elements in Protecting Tenure—Loss of Title Through Adverse Possession—Encroachment Upon Private Property.

5 MARKING RIGHT-OF-WAY LIMITS 32
Advantage from Marking Lines—Special Plan for Marking Lines—Surveying the Lines—Establishing Monuments.

6 BENEFITS FROM THE RE-SURVEY 33
Encroachments Discovered—Means Adopted to Remove Encroachment—Advantages Gained by the Survey—Cost of Survey Justified.

7 THE PARTY WALL LAW 35
Party Wall Defined—Only Walls of Buildings Included—Application of Statute to Railroad Property.

8 LATERAL SUPPORT 36

9 THE DAY IN COURT 36

10 ASSESSMENT FOR STREET IMPROVEMENTS 36

CHAPTER III

DRAINAGE OF ROADBED AND TRACK

11 CURING WATER POCKETS A MAIN CONSIDERATION 38
Clean Ditches—Water Pockets—Effect of Water Pockets—Essentials in Cure of Water Pockets.

12 CLEANING SIDE DITCHES 39
Clean Ditches Essential—Cleaning by Work Train—Ditching with Narrow Gage Equipment—Ditching by Piece Work—Wheelbarrow Ditching—Steam Ditchers—Economy of the Ditcher.

13 SUPPLEMENTARY DRAINAGE 41
Cross Drains—Berm Ditches—Monolithic Ditches.

14 DRAINING WET CUTS 43
Drains on the Pennsylvania—The 6-in. Tile Unsatisfactory—Example of Tile Drainage—Advantages of Bank Protection—Practice Regarding the Main Drain—The Laterals—Location of the Drain—Gradient—Joint Openings—Expedition Desirable—Special Equipment—Pipe Drains on the Sante Fe—Economy of Tile Drains.

15 DRAINING EMBANKMENTS 50
Cause of Pockets in Fills—French Drains Most Effective—Method of Placing Drain—Example of a French Drain Installed in Fill.

16 DRAINING LEVEL STRETCHES 52
Red Shale Bottom—Cinder Sub-Bed Temporarily Useful—Wooden Box Drains—Cleaning the Drain.

17 DRAINING YARDS 54
French Drains Between Tracks—Sump Holes at Switches.

18 UNDERDRAINING SODDED BANKS 54
Cinder-Filled Trenches Useful.

CHAPTER IV

VEGETATION FOR BANKS

19 ECONOMY FROM USE OF VEGETATION 56
Extension of Use—Ditching Reduced—Variety Desirable.

20 SODDING 57
Protection Against Slips—Sodding on a New Line—Applying the Top Soil—Placing and Caring for the Sod—Expense of the Sodding.

21 STIMULATING GROWTH WITH STREET DIRT 60
Application of the Compost—Formula for Sowing—Cheapness of the Method—Effectiveness of Street Dirt.

22 HONEYSUCKLE 61
The Woodbine Variety—Usefulness of the Growth—Mowing the Vines.

23 ROSES 61
Rugosa, Humilis and Wichuriana—Cultivation of the Roses—Propagation.

24 ALFALFA 62
Fertile Soil Required—Clay Sub-Soils Favorable—Inoculating Soil Not Essential—Rye for Supplemental Sowing.

25 OCCASIONAL GRASSES AND SEDGES 64
Bermuda Grass—Irish Heath.

26 DWARF TREES 64
Pines, Spruces and Willows—Usefulness for Snow Breaks.

CHAPTER V

LABOR-SAVING DEVICES AND METHODS IN ROADWAY WORK

27 DISTRIBUTING OPERATIONS 67
The Work Train an Essential Force—Heating the Riding Car—Steam Derricks—Clam Shell and Drag Line Buckets—Work Train Accessories—Use of Buckets in Ditching—Proper Types of Cars for Ballast—Power Device in Re-Ballasting—Hand Cars and Motor Cars.

28 PICKING UP SCRAP 70
Saturday for Collecting—Loading with Crane.

29 GENERAL CLEANING 71
Disposing of Grass and Weeds—Cleaning Delivery Yards—Policing by Special-Duty Men.

30 CLEANING SNOW AND ICE 72
Usual Methods Employed—Snow Plows—Spreader Cars—Snow Melting Oils—Special Snow Equipment—Melting Snow as it Falls—Snow Fences—Selecting the Locations.

CHAPTER VI

ECONOMICS OF ROADWAY

31 GENERAL RECOMMENDATIONS 76
Selection of Right Methods Important—Methods in Order of Availability — Standard Ditching — Disposing of the Dirt—Widening Fills for Future Extensions—Buckets for Standard Ditching—Power Ditching Machines for General Cleaning—Economy of Machines for Deep Excavations—Old Tie Cribs—Economy of Proper Means and Methods.

CHAPTER VII

TOOLS AND THEIR USES

32 THE TRACK JACK, LEVEL AND GAGE 81
33 THE ADZ AND RAIL CUTTER 83
34 TIE TONGS AND RAIL TONGS 84
35 HAND CARS AND TRUCKS AND PONY CARS 84
36 THE TOOL GRINDER 86

PART II—TRACK

CHAPTER VIII

THE ESSENTIAL ELEMENTS IN MAINTENANCE OF TRACK

37 DRAINAGE, CROSS-TIE RENEWAL, LINE AND SURFACE 88
The Principal Elements—Standard Sections of Roadway—Clean Ditches Essential.

38 BALLAST CLEANING 90
Depth of Cleaning—Raise Out of Face—Frequency of Raising—Center-Bound Track—Raising After Tie Renewals.

39 CROSS-TIE REPLACEMENT 92
Features Rendering Ties Unserviceable—Importance of Complete Renewals.

40 LINE AND SURFACE 93
Program for Line and Surface—Policing Along with the Renewals—Organization.

CHAPTER IX

A PROGRAM FOR M. W. & S. WORK

41 PRACTICE ON A MAIN-LINE SUBDIVISION 96
Importance of Systematic Work—Program on a Main-Line Subdivision—Instrumental Tests—Seasonable Track Work—Noting Progress in Repairs—The Tie Program—The Ballast Program—The Rail Program—Use of Program in Minor Items.

CHAPTER X

THE TRACK OBSTRUCTION

42 LIMITATIONS IN MAINTENANCE OPERATIONS 102
Definition of Track Obstruction—Need for Limitations in Track Work—Means of Protecting Traffic—Reliable Flagmen Necessary—Limitations in Relaying Rail—Collateral Requirements—Limitations in Renewing Ties—Limitations in Raising Track—Limitations in Gaging Track—Limitations in Lining Track—Efficiency Tests.

CHAPTER XI

LABOR-SAVING DEVICES AND METHODS IN TRACK WORK

43 STATEMENT OF THE MORE COMMON ITEMS 107
Avoiding the Need of Respacing New Rail—Saving Effected by Square End Rails—Curving Rails—The Rail Layer—Cleaning Ballast with Screens—Special Method of Cleaning—Economy from Oiling Track Bolts—Pneumatic Drill and Hydraulic Bender—Rapid Track Wrenches—Special Lengths of Rail for Road Crossings—Use of Hardwood Ties in Crossings—Drainage at Crossings—Economy from Correct Gages—Pneumatic Tools for Tamping, Spiking, Adzing and Boring—Use of Locomotive Cranes—Drainage at Crossings.

CHAPTER XII

TRACK MATERIALS AND THEIR USE

44 TIES 115
Ties of First Importance—Treated and Untreated Ties—Common Methods of Treating—Object and Effect of Treatment—Symbols for Untreated and Treatment Ties—Grades of Ties—Rail or Plate Bearing Face—Placing the Tie with Heart Face Down—Piling and Handling Ties—Ties Renewed by Spotting—Renewals Out of Face—Handling the Old and New Ties—Alining Ties in Track—Permissible Variations in Spacing—Lining the Ends—Neatness Essential—Rules for Number of Ties—Rules for Spiking—Rules for Selection of Wood.

45 RAILS 122
Improvement in Method of Manufacture—Change in Carbon Content—Maintenance—Handling New Rails—Use of Rails Shorter Than the Standard—Arrangement of Joints—Bolting at Joints—Manner of Spiking—Expansion Openings—Precautions Against Buckling—Rail Defects Which Lead to Failure—Determining Cause of Failures—Branding and Stamping of Rails.

46 BALLAST 127
Function of Ballast—Sub-Ballast—Cleanness Essential—Cleaning of Center Ditch Not Always Required—Ballast Supply—Ballast Border—Removing Ballast for Snow Handling.

47 TRACK FASTENINGS AND ACCESSORIES 131
Rail Joints—The Splices—Pennsylvania Splice — Staggering Bolts—Track Bolts—Nut Locks—Spikes—Tie Plates—Maintenance of Joints—Renewal of Splices—Tightening Bolts—Maintenance of Bond Wires—Special Maintenance Required at Insulated Joints—Examination of Joints for Defective Rails—Renewing of Block Joints—Rules for Tie Plates—Types of Tie Plates on the Pennsylvania—Application of Tie Plates—Use of Rail Anti-Creepers—Maintenance of Rail Anti-Creepers—Tie Rods and Tie Spacers.

CHAPTER XIII

PRACTICE IN RAIL RENEWALS

48 LAYING RAIL IN MAIN LINE TRACKS 139
Planning the Work of Renewal—Changing Tie Plates—Fixing the Point of Beginning—Preliminary Tie Spacing—Attaching the Splices — Providing Necessary Protection — Quickness of Action Essential—Detailed Operation in Relaying Rails.

49 LAYING RAIL IN BRANCH LINE TRACKS 143
The Practical Force—Preparatory Work—Protection—Detailed Method of Renewal.

50 REPLACING TEE RAILS WITH GIRDER RAILS 144
Where Girder Rails Are Required—Locomotive Crane Desirable—The Survey—Special Requirements—Details in Renewal of Connections—Tilting Ties at Step Joints—Ballast Renewals—Cutting Rails in Track.

51 CUTTING AND BORING OF HEAVY SECTION RAILS 148
New Problems Presented—Making the Cut Square—Methods for Different Lengths—Contour and Tempering of Cutters—Boring Holes—Grinding the Bits—Cutting and Boring with Torch—Rail Saws and Power Drills.

52 ECONOMICS OF RAIL REPAIR ON BRANCH LINE CURVES 150
Economy Essential—Limit of Safe Wear—Reducing Renewals—Frictionless Low Rail—Co-ordinating Speed and Elevation—Effect of Low Joints—Maintenance of Joints—Anchoring Track.

CHAPTER XIV

MAINTENANCE OF MAIN TRACKS

53 TRACK MAINTENANCE ON MAIN LINES 155
Track Maintenance Defined—Surfacing Out of Face—Loose Ties—Keeping Bolts Tight—Raising Center Bound Track—Light Raise Out of Face—Precautions in Raising—Eliminating Sags—Maintenance Surfacing—Lining Tangents—Lining Curves—Lining Done Gradually—Gage Correction—Attendance of Signal Forces—Eliminating Joints from Road Crossings.

54 TRACK MAINTENANCE ON BRANCH LINES 161
Points of Difference—Comparison of Maintenance Features—Surfacing in General—Detailed Method of Surfacing—Degree of Maintenance—Importance of Lining—Practice in Lining Track—Shimming Track.

55 MAINTENANCE THROUGH TRACK TANKS 165
Track Tanks Feature of Eastern Roads—Essential Provisions at Track Tanks—The Cross Drains—The Paving—Thawing the Ice—Beautifying Water Stations.

56 MAINTENANCE IN TUNNELS AND OVER LONG BRIDGES 169
(a) *In Tunnels:* Close Joints Essential—Preserving Clearances—Renewals at Night—Need for Ventilation—Means of Ventilation—Rules for Safety—Precaution by Engine Crew—Watchmen Essential. (b) *Over Long Bridges:* Depth of Ballast—Increased Maintenance—Longer Ties at Ends of Bridges—Anchoring Rails—Battered Ends—Watching Fires—Cleaning Bridges—Steel Guard Rails.

CHAPTER XV

MAINTENANCE OF YARDS AND TERMINALS

57 ORGANIZATION FOR REPAIR 177
Lower Degree of Maintenance—Typical Gravity Yard—Assignment of Yard Forces.

58 STORAGE AND DISTRIBUTION OF MATERIALS 178
Storing at Head of Ladders and at Humps—Usefulness of Work Train.

59 USE OF TRACKS 179
In Various Yards—Alternative Program Desirable—Co-operation Essential.

60 APPLICATION OF TIES AND OTHER MATERIALS 181
Digging in of Ties—Surfacing After Renewals—Installing Switch Ties—Renewal of Frogs and Switches—Track Accessories.

61 LINING AND SURFACING 183
With Use of Track—Gaging After Lining—Surfacing Under Traffic.

62 POLICING AND PATROLING 185
Policing for Safety of Men—Policing for Conservation—Trackwalkers—Lamplighter.

63 COLLATERAL DUTIES 186
Picking Up Spilled Lading—Transferring Heavy Material.

64 SAFETY IN YARD WORK 187
Safety of Men—Safety of Movement.

65 PREPARATION FOR WINTER 187
Concentrating on Switch Repair—Digging Out Switches and Connections.

CHAPTER XVI

MAINTENANCE PROBLEMS AND METHODS USED

66 REBALLASTING WITH STONE 189
Inadequacy of Cinder Ballast—Amount of Raise—The Survey and Plot—Depth of Stripping—Precautions Against Buckling—Tie Renewals—Equipment and Supply—Raising the Track—Lining and Dressing Up—Ballasting without Raising—Tie Renewals on Two-Year Basis—Tamping the Stone Under the Ties—Drainage Through Center Ditches and Cross Drains.

67 PUTTING IN SERVICE AND MAINTAINING A NEW LINE 192
Early Establishment of Full Speed—Arrangements for Throwing Into Service—Operating Question Involved—The Fill of Gravel Throughout—Complication on Account of Track Tanks—Sub-Grade Drained by Bed of Cobbles—Surfacing at Ends of Bridges—Ultimate Economy of Large Force.

68 RAISING AND SHIFTING A SIX-TRACK MAIN LINE 197
Maintenance Problems—Advantages Sought—Problem of Gradient—Density of Traffic Required Sunday Work—Organization for Track Raising—Progress Planned—Equating a Grade Through a Train Length of Distance—A 20-in. Difference of Level for Adjacent Tracks—Tilting a Four-Track Bridge—Shifting of a Two-Track Line—Absence of Casualties.

69 IMPROVING A SUBDIVISION AFTER NEGLECTED MAINTENANCE . . . 202
Deterioration of Roads—Improvement in Industrial Conditions—Determining the Cause of the Defective Maintenance—Relining the Tangents—Adjusting the Curves—Correcting the Grades.

CHAPTER XVII

ECONOMICS OF TRACK LABOR

70 GENERAL CONCLUSIONS BASED ON EXPERIENCE 207
Economies Developed in Special Problems—Track Forces Relieved of Irregular Duties—Sufficient and Uniform Forces—Practical Lengths of Sections—Semi-Skilled Work Allotted to Track Forces—Special Duties Performed by Designated Employees.

CHAPTER XVIII

SPECIAL DUTIES IN THE M. W. DEPARTMENT

71 DETERMINING THE CAUSE OF TRAIN ACCIDENTS 211
Preliminary Investigation—Frequent Causes of Accidents—Side Bearings — Wheels — Couplers, etc. — Derailment at a Switch Connection—Derailment on a Curve—The Accident Committee.
72 PATROLLING THE TRACK 214
Need of Track Watching—Routine Duties—Incidental Duties—Protection of Property—Tamping Low Joints—Night Patrolling — Checking Performance — Track Experience Needed—A Knowledge of First Aid Desirable.
73 PROTECTING THE HIGHWAY CROSSING 218
Physical Features at the Grade Crossing—Source of Supply for Watchmen—Selection of Watchmen—Special Instructions for Government of Crossing Watchmen—Hours of Protection—Points in Protecting Crossings—Proceed Signals to Travelers—Handling Gates—Flagging Trains—Observing Hours for Protection—Loitering—Watchman's Duty in Accident—Testing Performance.
74 POLICING THE RIGHT OF WAY 224
Policing Good Housekeeping—Importance of Policing—Leveling and Bordering Ballast—Ditches and Cross-Drains—Mowing Grass and Weeds—Disposing of New and Old Ties—Picking Up Scrap—Policing for Safety of Men—General Cleaning—Landscape Gardening—Uniformed Track Gangs.
75 CO-OPERATING FOR SAFETY IN MAINTENANCE 229
(a) Safety in Distributing Operations: Handling Ties—Riding on Cars—Obstructing Tracks—Handling Rails—Handling Frogs and Switches. *(b) Safety in Operation of Hand Cars and Trucks:* Safety Rules—Supplementary Rules. *(c) Safety in Track Repairing:* Co-operation of the Men—Overlooking Necessary Items—Men Working Alone—Track Work on Trestles—Care in the Use of Bars—Separating Men for Safety and Performance. *(d) Safety the First Duty:* Safety an Individual Responsibility.
INDEX 237

LIST OF ILLUSTRATIONS

The section headquarters . . . . . Frontispiece
Right of way defined by wire fence with concrete posts 32
Installing a tile drain 45
The pipes are packed in straw 45
Cross section of roadway with drain applied 46
Cross section of roadbed laid with pipe lateral drains 48
Installing a French drain in fill 51
Cross section of wooden box 53
Sodded slopes protected by cinder underdrains 54
Sodding a slope 57
Spruces used for snow breaks 65
A section gang on the motor car 69
Ordinary design of snow fence 74
Pony car moved properly 85
Standard sections of roadway 89
Surfacing on main line 94
Well policed stretch of road 100
Locomotive crane handling track material 113
Methods of marking ties with hammer brands 117
Proper and improper methods of piling ties 118
Renewing ties on main line 121
A. R. A. type B 100-lb. rail and splices 125
Ballast leveled to the standard section 130
Main track relaid with new rail 141
Layout of industrial yard 146
Rail anti-creepers help to maintain expansion openings 153
A well-maintained tangent on main line 158
A curve on main line 159
Paving at track tanks 166
Solid ballasted deck trestle 173
On the Bristol new line 193
Cross section of roadway at Bristol tanks 195
Layout of tracks at North Philadelphia 198
Maintenance of correct grade through interlockings. 205
The trackwalker should travel facing traffic 214
Where efficient patrolling is specially needed 217
Inspecting a well policed road 224
Bridge warnings properly maintained 227
Danger in alighting in front of a car 232

ROADWAY AND TRACK

INTRODUCTION

About the beginning of the present century there was crystallizing in the minds of railway officers the thought that maintenance practices required readjusting, in order to bring about a degree of uniformity for roads in the same class and to effect ultimately a complete standardization along economic lines. In the intervening years attentive study has been given the several problems, many elaborate experiments have been conducted and liberal discussion has been had, both in committee and through the pages of the railway journals. Much has thereby been evolved that has tended toward the elimination of old errors and the establishment of more correct methods. This has been particularly true of roadway and track, the two principal items in maintenance of way. While it is undeniable that at this time no two roads agree entirely in their standards and practices, it is also a fact that the general practice of any two of the roads is not greatly divergent.

Many of the larger systems have adopted specific rules for maintenance, and these are embodied in their several books of instruction for the government of the maintenance-of-way department. It is interesting to note how nearly alike are the rules of all these roads, even to minute elements of phraseology. Only in the detailed methods of performing a particular item of work prescribed under the rules is a large difference observable between individual roads. The rules stated are necessarily of a general character, since they embrace all phases of maintenance. Several books would be required to cover in detail the entire field of railway maintenance. Only by limiting the scope of the inquiry to one or two divisions of the subject can the matter be held within the compass of a single book.

It has become well recognized that standardized methods are desirable on a particular road, and it follows that methods

or practices which are economical on one road ought to effect a saving on other roads similarly operated. The period of practical test in maintenance is now past. The unusual traffic incident to a world war has been carried successfully; the occurrence of severely restricted rail and tie replacements has not worked irretrievable damage to the physical property; organization among the maintenance-of-way forces may be expected not to complicate the question too seriously; the expedient of government control has been applied and its conclusion reached. It seems an opportune time, therefore, to give earnest consideration to the methods, devices, and practices which have supplied favorable results in past maintenance of roadway and track. No amount of theorizing will solve the several problems in these two items of railway work. The answer is to be found only in the everyday experience of the man on the track. It is safe to say that all maintenance rules are based upon the observation of some practical trackman, communicated through various channels to the authority charged with promulgating such rules. After the announcement of the rule it is subjected to criticism from the observation of other men, and stands or vanishes as its usefulness is proved or disproved through exhaustive trial.

It would be interesting to determine, if such were possible, why the roads have been slow to adopt uniform methods in maintenance. The problem is unquestionably a far-reaching one, even though it involves no very radical changes in the existing standards. There is, of course, conflict of opinion to be reckoned with. Many operations can be performed in several different ways, all of which appear to be equally good; but when the processes are closely analyzed, one will disclose a shade more of economy than the others. If all the work of maintenance were standardized, the saving effected in each separate item would amount in the aggregate to a considerable figure. There would be the furthur advantage of uniformity of result. For example: a freight car will interchange among many different roads; it would be better for the car to travel its entire journey over medium railroads, than partly over first-class and partly over rough roadbeds. A passenger riding between New York and Washington, has

the satisfaction of his trip determined not by the nearly perfect roadbed almost all of the way, but by the few sections of rough track encountered here and there.

The need of a better track structure has been a live question in maintenance, as well as in construction, during all of the 20 years now past. The first deficiency sought to be corrected was the inadequate drainage afforded the track in cuts. Not until the ditches were excavated three feet below the top of the tie was measurable relief from pumping joints obtained. Five years later a crusade was begun to remove the dirt that was fouling the ballast. In another five years a program of work was determined upon as one of the essentials in economical maintenance. At the present time labor saving devices and methods are recognized as the principal dependence for overcoming the handicap of labor shortage and inefficiency. Fortunately many maintenance men, who saw service throughout the whole of this transition period, are still in the harness. It behooves the younger men, who eventually will take over the direction of work, to absorb the ideas born of their long experience, to the end that maintenance shall not go backward.

The roads are deeply concerned with the question of education of their men, not alone the heads of departments but foremen as well, in the accepted standards for maintenance of the property and in correct methods of work. The essential object of all maintenance writing is to interest and inform the older men, while affording the newer men instruction in practices the utility of which they can prove for themselves in their daily occupations. This reading only supplements the practical training they acquire while working on the track. A broader study of the problems of the track will not only stimulate the men to greater mental activity, but will tend to create a degree of interest in their work, which in turn will effect a larger measure of contentment. Granted that labor is both inefficient and independent, it cannot help but be recognized that a larger output will be obtained by right methods, and by a judicious use of machines. It is a fact, observed by all who are in close touch with labor forces, that the most indifferent laborer will be spurred to greater effort

if a contrivance for saving labor, or conserving safety, is employed. By way of illustration, men will resent being required to carry the heavier rails a considerable distance, when the use of a pony car can be obtained readily.

The efficiency of work, other things being equal, is directly dependent upon the standards followed, the supervision afforded, and the machines available for saving labor. A comprehensive study of the practices that have proved effective on a typical road will supply the knowledge essential to intelligent handling of the detailed problems of roadway and track everywhere. While these are mainly problems of engineering and economics, the conclusions obtained are within the province of all who direct labor. Even though a road may have its own maintenance rules, (and it is only proper that these should be observed to the letter), it is believed that a critical analysis of the practice on the Pennsylvania cannot prove otherwise than constructive. Nearly all accepted rules of maintenance may be traced to the investigation and recommendation of the various standing committees of the American Railway Engineering Association, supplemented by those of the Roadmasters' and Maintenance of Way Association, these two associations being composed of representative men from all the railroads of the United States. It may easily be found wholly practicable for the roads to adjust their detailed maintenance to uniform standards in the not distant future.

PART I ROADWAY

CHAPTER I.

THE ESSENTIAL ELEMENTS IN ROADWAY MAINTENANCE

1. A Summary of the More Important Points.

Scope of Roadway Work.—Roadway in its broadest sense includes all that pertains to the right of way but more especially the roadbed together with the slopes of excavations and embankments. Prior to the advent of the present century roadway maintenance consisted almost entirely in ditching the cuts, repairing the slips, removing the slides, and mowing the grass and weeds. The legal protection of the property, the promoting of vegetation, the installation of under drainage, a comprehensive system of policing, were given scant consideration because their value was little understood. With the newer practice in railway maintenance has come a keener appreciation of the advantages, both physical and aesthetic, of attention to all the features named.

Legal Protection, Vegetation, Drainage.—The losses to which the railroads have been subjected in the past, through unresisted encroachments, have shown the importance of both a knowledge of the legal points and a system of apprehending and defending against unlawful occupation. Persistent effort toward promoting the growth of vegetation on the slopes has resulted in a marked reduction in the number of slips and slides, and in some places has totally eliminated the ditching that had been perennially necessary. The improvement in the appearance of the road has been appreciated by the traveler who regards it as no small item in the enjoyment of his trip. The constant drain upon the track labor to repair rough places developing solely because of a lack of drainage, has led to a study of the conditions of soil that produce them and a search for their remedy. It is believed that methods are now known which modify, and in many cases entirely eliminate, such trouble.

Drainage Most Essential.—It may confidently be stated that for all kinds of road the essential feature is thorough drainage, both of the surface and sub-bed. The design of the cross-section is based primarily upon supplying this advantage, and the future maintenance is directed mainly to that end. Water is the track foreman's inveterate enemy. Whether his road is stone, or cinder, or dirt-ballasted, the condition that most reflects upon his efficiency is pumping of the joints. This is only the visible sign of an interior defect, and points to a larger duty than simply surfacing the low joints which result. The cause that produces the pumping must be found and a remedy applied without delay. The trouble is nearly always one or more of three things: ineffective side ditches, foul ballast, or the presence of water pockets in the roadbed. For adequate drainage, the ditches must be kept clean, the ballast renewed at proper intervals and the water pockets be given an outlet.

Subsidiary Items.—A further element of importance in maintenance is the physical protection of the slopes. This is mainly accomplished by vegetation, but berm ditches, and rip rap or paving where necessary to prevent erosion, are useful adjuncts. The utility of berm ditches, (and in this class may be included those ditches which intercept the first rush of water although not placed above the slope of a cut), has become better appreciated of late years. Their main function is to keep as much of the flow as possible entirely away from the railroad. That which falls directly upon the track is all that should ever trouble the roadbed.

Policing Justified.—The policing of the roadway is a feature of importance because aesthetic standards have been raised, and the keen competition of the passenger lines for business has made the attractiveness of the right of way a very decided asset. The passenger's preference of route is often an index of the routing of his goods. Thus, policing is a strong bid for both passenger and freight business. The extent to which beautifying is carried out on some roads is of course out of the question on other less prosperous lines. The matter of neatness applies everywhere while its cost is inconsiderable, and often is more than met in the value of the scrap and other small materials recovered.

Protection of Title.—The protection of the company's title to land is not less in importance than the physical maintenance of its property. The enjoyment of all the rights to which it is entitled, and the observance of its duties to its neighbors, can only be completely realized by a full knowledge of what its rights and duties are. The preservation of correct records of the right of way, and the physical establishment of property lines by posts or monuments, are matters which are becoming more important with the development of habitation along its lines and by an ever-increasing industrial expansion. Heretofore these subjects have been mainly for the engineer; but with the increasing scope of the duties of both the roadmaster and foreman, they have become of general interest to all.

Labor-Saving Methods.—Labor-saving devices and methods are receiving increased attention in maintenance-of-way work on all roads today. Their usefulness as an offset to labor shortage and inefficiency is unquestionable. The employment of machines where possible is desirable also to avoid the many minor accidents to which the track forces have been subject in the past. The broad provisions of workmen's compensation laws make it imperative that the roads shall strive earnestly to reduce the number and seriousness of such accidents. A clearer conception on the part of both the foreman and his men of what methods are proper, will contribute to the employees' co-operation in avoiding these mishaps.

Use of Tools.—The correct choice, care and use of small tools also are important, not only in increasing efficiency, but in promoting the safety with which work shall be done. The proper selection and use of tools have resulted in a marked saving in the expenditure for new tools and an increase in the output of the section forces, even though these are reduced both in number and quality through present labor conditions, and in the avoidance of many accidents. While the small tools used by the section forces are principally employed in track work, it has seemed best to include the chapter on their use in the Roadway division, especially because they are classed as roadway tools.

Program of Work.—The organization of the working forces for the repair either of the roadway or track is an important element for progress along economic lines and deserves careful attention. The work pertaining to roadway cannot be systematized as readily as track work, and therefore no specific cases have been discussed, such as was possible for items like ballasting or rail laying. A study of the indivdual case will best determine its proper conduct; but many points are given which will aid in reaching a solution. In the division of Track there is shown a suggested program for M. W. & S. work. While the principal items relate to track repairs, the detailed scheme of work to be engaged in includes certain features that belong to roadway repairs. A careful study of this program will convey helpful suggestions.

CHAPTER II

THE RIGHT OF WAY

2. General Principles.

Definition of Right of Way.—Literally defined, the right of way is that by virtue of which the railroad holds its permanent way. It usually is land owned in fee simple or obtained by condemnation; but it may include an easement over another's land, or the right to cross or occupy the streets of a municipality, or the privilege from the federal government of bridging a navigable river. Improved land which is not used for railroad purposes, or that which is vacant and not intended for such use, is not classed as right of way. Such land is usually in charge of the real estate department and only of incidental concern to the maintenance officer.

Custodians of the Property.—The supervisor is the natural custodian of the right of way; the foremen are his lieutenants and the track walkers are the roundsmen. It is essential that all of these should know the exact extent of the Company's ground and the rights that are otherwise enjoyed. It is further necessary that the supervisor shall definitely understand the legal principles of property tenure, in order to be able to handle promptly and decisively such matters when they arise. Not infrequently while a legal question is being determined occupation is becoming established and is growing increasingly difficult to resist. It is an old adage that possession is nine points of the law, and it is a legal axiom that he who would sue to dispossess another must first show a better title. The surveyor recognizes fully that in tracing property corners he must if possible make a location in accord with the record, and yet **not in conflict with possession.** The importance of resisting a trespass is therefore self-evident.

Adverse User and Adverse Possession Defined.—Property questions are so simple that they may nearly always be de-

cided by the rule of common sense. There are, however, certain distinctions which can only be determined by a working knowledge of the principles of legal technology. It is necessary to understand fully the legal meaning of the terms adverse user, and adverse possession. In the case of those traveled ways over the company's land which nowise pertain to the operation of the railroad, an acquiescence without objection in the public use either by foot or vehicle would indicate an intention to dedicate, and this would constitute an adverse user; but when these ways are the approaches to public facilities of the railroad, such use is not adverse and no permanent easement would result therefrom. As regards possession of ground, the use must be adverse to the **interest** of the owner, and it must be continued in the **manner** prescribed by the statute, as well as for the required **time.**

Difference in Rule for Individual and Company.—While an individual may obtain title to land by adverse possession, continued for the prescribed term of years, it is a rule of law that a corporation cannot thus gain an ownership, although a continuing easement for the use of a right of way may be so acquired. It is common belief that lines do not under any circumstances become fixed by acquiescence in a less period than 20 years. This is not correct, as road lines may by statute become conclusively fixed in 10 years; and there is no particular time for concluding ownership between private parties who tacitly agree to a particular line of division.

3. Legal Principles Affecting Right of Way.

Lines Referred to Tracks or Streams.—The boundaries of the right of way usually are parallel with the center line, which is then known as the center line of right of way. Although this line originally bore a direct relation to the tracks it does not, as some suppose, shift with them. When the descriptions in the deeds are referred to it, its position becomes fixed, and it should be permanently located by means of monuments and by reference data. In those cases where the property limit is a stream, with the single exception of navigable rivers, ownership extends to the middle of the stream, no matter what changes in its course the stream may undergo. In the case excepted, the federal government owns

the bed of the stream between low water lines, and its direct control is vested in the Secretary of War. The matter of conserving the natural means of discharge for storm drainage is scarcely less important than the protection of title; every water course should be shown on the right-of-way maps, to be used as evidence in case an attempt is made to close such outlets.

Eminent Domain Limited to Land.—The fullest use of property of course is obtained when it is owned in fee simple. When purchase is impossible, the acquisition must be through condemnation under the government right of eminent domain. The law permits the taking only of land which, however, is not alone that required for the road bed, including the slopes of excavations and embankments, but also that which is needed for borrow pits, for new courses of diverted streams, for stations and shops, and for every other facility intended to be used by the railroad in the exercise of its corporate object. The right of eminent domain thus does not extend to a railroad company the power to condemn for the use of its engines, or for any other use, water of a stream over which it may have built its roadbed.

Restrictions Removed by Purchase.—Where a right of way is granted merely as an easement during such time as it shall be used for the purpose of a railroad, it may be lost by intentional abandonment, evidenced by the taking up of a track, or through long disuse of the facility. A right of way originally obtained by condemnation is by law bound by certain limitations and when acquired by license is often restricted as to use; but when the fee is later bought such restrictions cease. In the purchase of additional property it is always desirable to include in the new purchase the land covered by the easement.

Setting Back Water Lines.—The railroad as owner along an inland river can restrain proprietors below from raising or setting back the water lines, and in fact possesses all the natural rights that belong to a reparian owner. If a culvert through an embankment of a railroad should prove inadequate and the waters be set back to the damage of a private owner, no action will lie if it can be shown that the storm was of unusual and unexpected proportions. It is a well recog-

nized rule that only the ordinary and expected rainfall must be provided for.

Relative to Highways.—When a street forms the boundary of a property, ownership ends at the house line, but certain rights in the sidewalk attach to the abutting owner, and for this reason repairs of the sidewalk are generally the duty of the owner. If a public street or road should be legally vacated the abutting owners would take by law to the middle of the abandoned highway. When the municipal authorities change the grade of a street for a public purpose the railroad company is not liable to abutting owners for damages; when the change is for the benefit of the railroad, its liability would be unquestioned. The courts seldom fail to recognize the implied right of railroad companies to build across the highways, even where such construction necessarily curtails the public convenience in the use of the highway. The right is, however, subject to the exercise of the police power of municipalities. It is therefore always best to continue in place that portion of an abandoned track which spans a highway in cities or towns, in order to retain the right of crossing at some future time if desired.

Fencing the Right of Way.—If local acts do not impose upon the railroad the entire burden of maintaining fences, the law requires that the expense shall be equally shared; but participation may not be demanded until the owner has a **bona fide** need for the enclosure. A fencing statute cannot require the maintenance of a fence between the adjacent rights of way of two railroad companies, because such a fence would serve no useful purpose. Similarly such acts cannot compel the fencing in of a side track, nor the addition of cattle guards thereto, as the protection is not required by the character of operation over the siding.

Trees Overhanging the Right of Way.—When trees or artificial objects close beside the right of way endanger the company's operation, request may be made for their removal, and in case of refusal damages could be claimed, if such result, provided the cause of the injury is not an unusual and unforeseen circumstance. The principle is the fundamental one that an owner must so use his property as not to injure his neighbor. When branches of trees overhang a right of way owned

in fee, threatening interference with the telegraph line, the railroad company has the right to trim them; but it is always best to obtain the owner's permission in writing, if possible, since in the event of damage to the tree the courts are inclined to make a liberal allowance for sentimental value.

4. The Effect of Encroachments.

Elements in Protecting Tenure.—"The essential elements in the protection of right of way are proper records communicated by the real estate department, reliable lines established by the division engineer, and continual watchfulness by the roadmaster and foreman. If purchases and sales are not indexed, if right-of-way sheets are not corrected, if lines are not defined on the ground, the detection and removal of encroachment is rendered difficult. The shabby hut of the squatter, the misplaced fence of the adjoining owner, the long established path or driveway of the trespasser, each in time results in loss of property. The situation is more critical in cases where the original center line is destroyed, or where property lines are irregular, as in lots and blocks in cities, or where improvements are not present to mark the lines." Editorial in the "Railway Age."

Loss of Title through Adverse Possession.—The great difficulty that is experienced in dislodging squatters should emphasize the importance of preventing encroachments and, if they should occur, of removing them as expeditiously as possible. The consequence of an occupation permitted to continue until title is endangered, or perhaps lost, is sometimes quite far-reaching. The case of an important grade-separation project being held up for two years, during which a million dollar investment was inactive, is a striking illustration in point. Cases are not uncommon wherein the railroads have had to buy back for important work land that the right-of-way sheets indicated as being already owned. There have, indeed, been cases where it was impossible, by reason of the lost property having become part of a homestead, to repossess at any price. Necessary improvements are thus prevented by lack of attention on the part of those who should protect the company's possession.

Encroachment upon Private Property.—There is the other item of encroachment by the railroad upon the property of adjoining owners. Such encroachment is undesirable from all standpoints, and should be effectually remedied the moment it appears. The old saying of a stitch in time is aptly illustrated in such cases. If the means are afforded promptly to observe the approach of an erosion to the right-of-way line, a simple construction may arrest its progress; but if it is allowed to continue, nothing short of money compensation or the purchase of additional width, generally at an exorbitant price, will suffice to settle the claim.

5. Marking Right-of-Way Limits.

Advantage from Marking Lines.—The advantage derived from visibly defining the limits of the right of way are being accentuated through the increasing value of all lands. The litigation, which frequently ensues from a disputed ownership, is not only a source of trouble and expense, but its worst effect often is the inability to use the property for extensions or improvements while the matter is being determined. Controversies are impossible when the dividing lines are so plainly

Right of Way Defined by Wire Fence with Concrete Posts

marked that all concerned may see, and the railroads are coming to a better appreciation of the value of thus indicating their property bounds.

Special Plan for Marking Lines.—The plan adopted by one road, for use at places where no buildings or fences are present to mark the lines, is to plant wooden ports at all cor-

ners and between these at points 400 ft. apart on tangents and 200 ft. apart on curves. The posts are usually 4½ in. square and 4 ft. 6 in. long and project 2 ft. above the ground, this portion being painted white. To be fully effective these posts should be maintained carefully, and be repainted from time to time as may be necessary.

Surveying the Lines.—Preliminary to setting the posts, a careful survey should be made by a party from the division engineer's office. It is the practice of many divisions thus to establish all property lines, and this is certainly safer than a location by the supervisor, since property records are seldom entirely correct outside the division offices. While it is important that the supervisor shall know the exact extent of the company's holding, there is always the possibility that new conveyances may not have been promptly certified to him. The law in cities usually requires that street lines shall be defined by the city surveyor, and it is customary for this official to establish lot lines also when so desired. Such a survey is not only reliable but authoritative.

Establishing Monuments.—The marking of the right of way is not of maximum use unless care is taken to correct the lines for subsequent property acquirement or surrender. It is the practice on some roads to plant monuments at the corners of new conveyances, which is based on a sound principle, since the existence of a monument is evidence of the original survey, whether or not it is called for by the recorded plat. These marks should still be supplemented by the attention-compelling white painted post.

6. Benefits from the Re-Survey.

Encroachments Discovered.—As a result of defining the right-of-way lines on an eastern road, a surprising number of small irregularities were found, and some that were of greater consequence. Many gateways were noted opening upon the right of way; paths were located crossing the railroad, and just as frequently extending longitudinally, a more difficult trespass to resist; and the edges of the company's land were here and there going under the plow. At one point the fence along a homestead was several feet within the line, and occupation could be proved for nearly the required time.

The saving of this ground allowed a cut to be widened to the standard section. Just opposite, where land was needed for this purpose, the owner named a price of $2,000 per acre for farm land in a country district. Encroachment by permanent structures was seldom encountered, as there almost always is proper diligence in this respect.

Means Adopted to Remove Encroachments.—Vigorous efforts were made to discontinue the intrusion through the gateways, and where this could not be done agreements were insisted upon. The driveways were effectively blocked by heavy posts, and signs forbidding trespass were erected at the paths. Where title to the land being farmed was through purchase, leases were obtained, thus establishing the company's ownership, when ultimate recovery of possession was rendered easy. Care was taken that no land originally obtained by condemnation was leased; as, except for purposes incident to the company's operation, such leasing is unlawful. Where unrecorded wire crossings or other similar facilities were found, they were quickly brought under agreement.

Advantages Gained by the Survey.—The advantages in having the lines defined are thus manifold and the disadvantages few. In addition to the main object of preventing encroachment there are economic benefits which are quite measurable. In rugged country where the right of way is usually unfenced, the mowing and cutting of brush, whose main object at such points is the maintenance of a clean right of way as a defense against fire claims, is usually done over a wider swath than necessary because the property limits are not known, and this increase of roadway expense accrues year after year. The performing of work outside the property limits is not only wasteful, but such action sometimes leads to embarrassing complications. The fact of work having been done upon a private roadway by company forces, even though done by misconception, would in the event of an accident operate to deprive the railroad of a non-suit.

Cost of Survey Justified.—The expense incident to a property survey is, of course, widely different for dissimilar situations, but there can be no doubt that the advantages derived exceed the cost many times over. Then there is the fact of stewardship, which alone would justify the means taken to

guard the company's holding, even if not one irregularity were uncovered.

7. The Party Wall Law.

Party Wall Defined.—A party wall is a wall upon the line between the premises of adjoining proprietors which each has a right to employ as a support for his structure. It is a form of exercise of police power for the economic use of property, and is mainly applied in cities. While the regulation is of ancient origin, it is distinctly defined by statutes in most of the states. These usually provide that it shall be built equally upon the lands of the adjoining owners, with its maximum width limited by different conditions, and its original expense of construction borne by the proprietor who first uses it, but with half the expense a charge against the adjoining owner when he builds to it.

Only Walls of Buildings Included.—The application of the law is sometimes misunderstood, since not all walls between adjoining properties are included. In fact, the only wall to which the law does apply is one that is part of a building. A wall forming or supporting a fence, or one used to retain the ground, is not included within its provisions. In a case wherein acquirement of property for a right of way necessarily requires the continuation of an existing party wall, it is well to know that the adjoining owner could be enjoined from making use of it for displaying any kind of a sign, even one painted thereon.

Application of Statute to Railroad Property.—While there is no question of the equity of the party-wall statute as between owners presumed to hold for a common object, it clearly cannot be held to apply against the property of a railroad, owned and intended to be used as a right of way for tracks. Thus to apply the law with no reciprocal benefit possible to the railroad would plainly amount to confiscation. In the author's somewhat extensive acquaintance with conditions surrounding a considerable section of the City of Philadelphia, only one case is known of occupation of the right of way under the party-wall law, and this is recognized to have been an error.

8. Lateral Support.

The common law requires that an owner shall be protected in the use of property at the contour that nature has provided, or that which it held at the time of his purchase. An adjoining owner is thus prohibited from raising or lowering the level of his ground without supplying adequate support for his own or the adjacent land, and this support must be provided without any sacrifice whatever by the neighbor. No act of a municipality can abridge or change this duty. Such a circumstance in railroad practice most commonly occurs when an adjoining owner lowers the contour of his yard to obtain increased storage capacity. For whatever depth there is below the natural level of the ground he could be compelled to provide a sufficient retaining wall entirely on his own ground.

The obligation between a municipality and the railroad company is not so clearly defined, and such cases are usually disposed of by a mutual agreement. It can safely be stated that in the absence of such understanding the railroad company must be afforded the advantage of its day in court.

9. The Day in Court.

When it is necessary for the municipality to take property for public use a day is appointed for a hearing before the jury of view or the commission, as such bodies are now more generally constituted. At this hearing both the damages and benefits are assessed. If an owner suffering damages fails to appear he is prevented ever after from bringing forward his claim, and must also accept his assessment for benefits. It therefore becomes a matter of consequence to the railroad, not only to have its representatives present, but to delegate this duty to those who are familiar with all the various questions involved. Counsel is most essential, but the real estate expert is an important participant, and the supervisor, who, by reason of his intimate detailed knowledge of the local situation, is generally selected as the engineer, will have a responsible function in the proceeding.

10. Assessment for Street Improvements.

Street improvements include all the betterments of a legally established highway, such as grading, curbing, paving, sewer-

ing, water service, etc., for which the municipality is responsible. The theory of assessment is benefit, but the rule requires that the benefit shall be tangible and not speculative. The opening of new streets, the widening of existing streets, the grading, paving or sewering of streets, unquestionably are material improvements from which the railroad derives indirect benefit. So long as the development does not render its land more valuable for railroad uses, an assessment can not legally be laid. If the street were an only means of ingress and egress to and from a station the direct benefit would be evident. When a sewer provides for entrance of the station drainage, even though it may not be used, the benefit would be presumed to exist. When a new street is opened across railroad property it is customary for the railroad to include in the damages a sum for street improvements upon the theory that such assessment will later be laid.

CHAPTER III

DRAINAGE OF ROADBED AND TRACK

11. Curing Water Pockets a Main Consideration.

Clean Ditches.—A maintenance rule of the Pennsylvania states very aptly that effective drainage is most essential. The standard cross-sections for cuts on all well maintained roads specify a depth of side ditches sufficient to drain not only the ballast but the sub-bed as well. The rules also require that the ditches shall be kept clean, and especially forbid the depositing of cinders in them, since these greatly impede the flow of water. The practice of protecting the slopes with vegetation is becoming more common, which not only reduces the amount of cleaning necessary, but furnishes greater assurance that the cleanness will always be had.

Water Pockets.—The stability of the roadbed is still limited by the presence beneath the tracks of what are known as water pockets. A careful study of the cause, prevention and cure of these pockets has been made in late years, and the matter is now fairly well understood. When present in fills, they are unquestionably due to the occurrence of a layer or bed of porous material surrounded by a less pervious soil, which forms a basin to hold the water seeping through from the roadbed. In the case of the deeper cuts these pockets receive water that wells up from springs, undiscovered when the original construction was made, or whose presence has since been neglected.

Effect of Water Pockets.—The tendency of this accumulation of water is to soften the roadbed so that it does not furnish uniform support to the track structure. The constant raising of the track with ballast at the soft places serves to concentrate the load, and this causes the walls of the pockets to be pushed upward so as to block the flow from the ballast shoulder and to obstruct the drainage in the ditches. The proper remedy is to tap the bottom of the pockets and drain

off the water that is being held. This is especially true of quicksand pockets which form the worst possible roadbed condition. As is well known, the moment an outlet is provided for the water in such a soil it ceases to be a quicksand. The need of correcting quicksand pockets is insistent, as accidents have happened through a sudden breaking down of the track surface at such points.

Essentials in Cure of Water Pockets.—In all cases of subdrainage the essential requirement is a longitudinal drain of regular grade and smooth surface which will pass off quickly the water collected from the various pockets. The other requirement is a system of laterals to lead the water directly to the longitudinal drain. Although the scheme best suited to a locality can only be decided by a practical analysis of the local conditions, a knowledge of the methods that have proved useful at other points will help to determine the method applicable to the individual case.

12. Cleaning Side Ditches.

Clean Ditches Essential.—The primary means of draining the roadway is through the side ditches, supplemented by such cross drains as may be necessary. For all classes of road, it is required that the ditches shall be kept clean in order that the storm water may be diverted quickly from the roadbed. From one-fifth to one-third of maintenance expenditure is for roadway cleaning, which mainly comprehends ditching. Much study has been given to this item of work and a consideration of the several methods practiced will supply the means for deciding upon the proper one to adopt for a particular situation.

Cleaning by Work Train.—The most common method of cleaning the ditches is by work train, although it is usually the most expensive one. The use of this means is generally justified by the long haul required for disposing of the dirt. It then becomes merely a question of employing an efficient force for the train, and of getting all the time practicable for the train to work at the locality. It is possible in many instances for the operating department to divert trains, so as to afford better facilities for the work train, and this should be done as a matter of conserving labor as well as for economy.

The practical force for a work train, where the ordinary distributing and ditching work is being done, is 18 laborers. When a continuous operation of loading dirt is in progress, the force may be limited only by the number of cars available, along with the prospective opportunities for work. In all work, it should be definitely determined that the laborers must be kept employed to advantage at the location while the train is clearing or is otherwise detained. Under the heading of labor saving devices, several methods will be given for saving labor in work train ditching.

Ditching with Narrow-Gage Equipment.—It is a common practice in ditching the shorter cuts, where the haul is not great, and proper clearance is available, to employ ditching cars drawn by a horse or pushed by one or more men. These cars hold from 1⅓ to 1½ cu. yd. and run on a 24-in. gage track, which may be commercial sections of prepared track, or track specially laid upon old ties with light repair rails. Good progress may be made by one man working alone, but when several cars are available, a gang of men will generally be preferable. The man assigned to work alone should be one who is dependable, and when a gang is employed, a competent foreman will be necessary. At the close of the day's work, the cars should be run in on a spur away from the main line, or, if no spur is in place, should be left dumped away from the main track. To facilitate drainage the dirt should be kept leveled down below the grade of the railroad while a ditching operation is in progress.

Ditching by Piece Work.—Where a special ditching improvement is planned which involves no element of haste, it is economical to assign definite sections to reliable men working alone, providing each with a pick, shovel, template, and in some cases, a wheelbarrow. Note is made of the daily performance of each man and preferably a premium is given for progress above the average or beyond a definite unit. This scheme has been tried out in a number of instances, and has invariably given good results.

Wheelbarrow Ditching.—Ditching by wheelbarrow is practical for any distance between 10 ft. and 200 ft. For a less distance than 10 ft., the dirt can be cast, and for greater distances than 200 ft., ditching cars, or in certain cases of infre-

quent traffic, the hand truck, can be used to better advantage. The time of cut watchmen can profitably be employed in ditching with a wheelbarrow at such hours as the established tour of patrolling permits. Runways are required for efficient use of wheelbarrows. When these cross the tracks, care is necessary that they are always kept clear of the rails. The practice of laying boards across the top of the rails is not permissible in any circumstance. The dirt should be kept leveled below the grade of the roadbed and should not be allowed to drop into the ballast.

Steam Ditchers.—When the ditching is heavy, a steam ditching machine is desirable, provided proper occupation of the track next the ditches can be had for at least one-third of the time. It should be noted that the operation obstructs also the adjoining track, and the traffic requirements thereon must be given consideration. The ditcher is specially useful where the dirt may be disposed of immediately by casting it upon the top of the bank. When it must be carried away, flat cars, provided with stakes and aprons to permit of the dirt being ploughed off, or convertible ballast dump cars similarly equipped, are required; and a spreader car is always a useful equipment. Air-dump cars are quite efficient, particularly when the dirt is wasted on fills. Ditching machines are invaluable in the removal of large slides, which work must be done quickly in order to open the road for traffic.

Economy of the Ditcher.—An example of the usefulness of the ditcher as a labor-saving device is supplied by the experience had upon the low grade freight line of the Pennsylvania. The road is double-tracked, and is laid through many deep cuts where earth and rock slides are frequent, and where the comparative newness of the road makes ditching a continuing operation. The cost of cleaning the ditches was reduced two-thirds by the use of the machine, and it was found that the first cost of a machine was saved in one year. The plan of operating the ditcher is to work in a cycle: when driven to cross over, the device works on the opposite side until again forced to cross over. Only seven men are carried on the ditcher at any time. It is frequently used for handling rails, ties in bunches, and heavy materials generally.

13. Supplementary Drainage.

Cross Drains.—The subsidiary means of draining the roadway are cross drains, berm ditches, paved gutters and monolithic side ditches. The cross drains, whose function is to drain the surface water from the roadbed into the side ditches, may consist of (1) a tie crib left open or a blind drain, either of which is kept clear for a depth of several inches below the bottom of the tie; (2) a wooden box drain open at the top; or (3), an iron-pipe. Care should be taken that none of these is placed under a rail joint, and if later renewal establishes a joint over one of the drains, the latter should be relocated at once. These drains facilitate greatly the drainage of the roadbed, and should be installed as frequently as may be necessary to serve that end. The drains need to be examined regularly to keep them free from rubbish, and the ends especially should be kept open. Iron pipe is preferable where a discharge must be provided at intervals for the center ditches on multiple track roads. They seldom need to be of greater diameter than 6 in.

Berm Ditches.—Berm ditches are necessary to prevent water coming over the top of a cut, causing erosion of the slopes, depositing dirt upon the tracks and sometimes creating a washout. The object of berm ditches is to intercept this water at least five feet back from the face of the slope, and carry it along the top of the cut to a point where it can drain away into a natural water course. It is sometimes not practicable to carry the berm ditch to the end of the cut, and it has to be carried down the slope of the cut and into the side ditch. This may be done by means of a paved gutter, discharging against a masonry head wall, or by conveying the water in a suitable pipe turned at its lower end to run parallel with the ditch. An intercepting ditch is sometimes required on ground which is level with the track, or even below it, to relieve the roadbed of an undue burden in drainage.

Monolithic Ditches.—In certain cases where the grade of the road is nearly level, and the width of the right of way limited, so as to preclude the deepening of the ditch to provide a practical fall, resort has been had to monolithic ditches, which may be laid on a grade as low as 0.25 per cent. The ditch is made with two surfaces, one following a modified

slope of the 7-ft. and the other coinciding with the slope of the cut for a height of 12 in. Several miles of these monolithic ditches have been in place on an eastern road for 20 years, and are still in good condition. They are practically self-cleaning in storms and only need to be swept clear of cinders along with the ordinary policing of the road. Special methods of protecting banks, particularly those along river courses, have been employed, but their description has no place here, because they are not of such general application as to be regarded as standard practice. The means employed for subdrainage of the roadbed and track in wet cuts, on fills and in level country, require detailed consideration and are illustrated by actual cases.

14. Draining Wet Cuts.

Drains on the Pennsylvania.—The Philadelphia to Washington line of the Pennsylvania was confronted for a long period with the problem of providing effective longitudinal drainage for a number of wet cuts. The problem was finally solved by the use of 12-in. glazed terra cotta pipe laid beneath one and sometimes both of the side ditches. There is now in place on that section of road a total of 67,000 lin. ft. of such pipe, occurring at 42 different locations, distributed uniformly over the entire division. Similar methods are extensively employed on many other roads, notably the Baltimore & Ohio and the Lehigh Valley, and upon all, the use of the tile drain is being extended.

The division referred to follows in a general way the "fall-line", or inner boundary of the coastal plain. The road intersects many water courses tributary to the Delaware river and to Chesapeake Bay, and in crossing the several water sheds is frequently located in cuts. Many of these cuts contain springs which formerly found their outlets in the surface ditches, not only interfering with the prompt discharge of the storm drainage, but also rendering the roadbed soft. The passenger service is frequent and a high rate of speed is maintained. There is a considerable freight traffic, consisting largely of perishable foodstuffs from the south for metropolitan markets, which is likewise moved on a fast schedule.

The 6-in. Tile Unsatisfactory.—To meet the requirements of this exacting service many schemes for draining these wet

cuts had been tried, each furnishing a temporary relief, but all eventually ending in failure. The most promising of them was a longitudinal terra cotta drain laid with open joints; but as the pipe was only 6 in. in diameter it soon clogged up with dirt. When the water no longer had an outlet, the unequal pressures in the soil caused the drain to buckle and eventually to become entirely disrupted. It was not unusual to find the pipes protruding vertically above the ditch. The present development of the method, in which larger diameter pipes are used, has been tested at certain points for a number of years, and there seems to be no doubt that the benefits are permanent.

Example of Tile Drainage.—A typical example is a cut 1,600 ft. long with the grade of the road descending from the middle in both directions at a rate of 0.4 per cent, and with the grade of the drain established parallel with that of the track. The draining of this cut was necessary to avoid excessive maintenance costs in lining and surfacing, and to afford as smoothly riding track at all times as was obtained at other points. It was the rule for the track force to spend one day each week in this cut, the extent of which was 1/10 that of the entire section. Thus, there was an excessive cost of maintenance, and the appearance of the road was unfavorable.

Advantage of Bank Protection.—The preliminary stage in the treatment of the case included the sloping of the wet bank and the developing of a growth of vegetation. This was accomplished in the short period of six months by the use of street dirt spread 2½ in. thick and sown with a mixture of grass seeds specially adapted to wet soils. This provision was necessary because of the extreme wetness of the bank, which rendered the digging of a ditch 4 ft. deep almost impracticable without this advantage. The two illustrations show the work of installing the drain in progress. As the photograph in the frontispiece indicates, the maintenance of this piece of road is now on a par with that of many other places where drainage deficiencies have never existed. The cost of lining and surfacing this stretch of road was formerly $440 per year and it was reduced through the placing of the drain to one-half this amount. As the labor cost of installing the drain was $260, this expense of the improvement was

Installing a Tile Drain

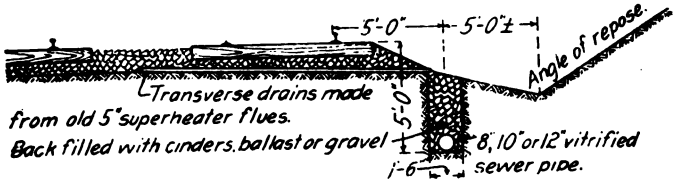
The Pipes are Packed in Straw

practically met by the saving in maintenance during a single season.

Practice Regarding the Main Drain.—As a result of experience with these drains, practice in a number of details has been definitely established. The pipe should nearly always be of 12-in. diameter, but if the requirements are moderate a 10-in. size will answer, and in exceptional cases, when the cut is short and not springy, 8-in. is sufficient. As the lateral thrust is considerable by reason of the close proximity of the track, nothing but double strength pipe is adequate, and similarly all broken or defective pipes should be carefully culled out. While it is generally desirable that both ditches be equipped, it is not always required. For most cases of single- or even double-track railroad the use of a number of cross drains of 6-in. iron pipe will render a single longitudinal drain sufficient.

The Laterals.—Blind drains, consisting only of a cinder-filled trench, are placed at intervals to lead the water from the roadbed to the pipes. The same result is also obtained by the use of tubes of small diameter laid transversely. These tubes need not be larger than 2- or 3-in. in diameter, and are most efficient when supplied with numerous perforations. Old superheater tubes, which are about 5 in. in diameter, are effective where springs occur in the roadbed. It is possible to drive the smaller tubes into the sub-bed if a pointed plug is first inserted; but for the larger ones the use of an auger is necessary. As the pipe progresses, the auger is turned in the pipe thereby drilling a clean hole for the tube.

Location of the Drain.—The most effective location for the



Cross Section of Roadway with Drain Applied

drains is 5 ft. from the gage of the rail and this will be, for most standard sections of roadway, also the distance from the

pipe to the toe of the slope. Thus, the system serves the double purpose of draining the water from the track and receiving that from the springs in the slope. A less distance from the track renders the pipe more liable to fracture from the weight of the traffic, and a greater distance does not answer fully the needs in draining the roadbed. The proper width for the excavated trench along an operated track is 18 in. The usual depth of the bottom of the pipe below the base of rail is 5 ft., which is the minimum that will avoid disturbance from frost. When the grade of the track is level and the cut a long one, it will be necessary to establish the highest point of the drain at the middle of the cut. The required grade of the drain will then effect an increasing depth of the pipe. In case no direct means of discharge is available, it is sometimes practicable to create a sump by blasting a hole to a depth where a porous soil obtains, the hole being afterward filled up with stones.

Gradient.—The pipes are placed generally upon the earth floor, but sometimes upon a floor of boards, and are located on a regular gradient established with a level. The least rate of fall that is practicable is 0.25 per cent. In extremely bad soils there is a possibility of the drain becoming distorted through the unequal pressures, a condition evidenced by a rising of the surface of the ditch. An excavation should be made at once and the regular grade of the pipe restored. This is done easily, and it is especially facilitated by the open joints of the drain.

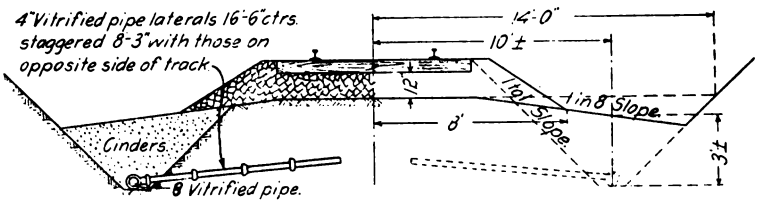
Joint Openings.—The opening of the joints should be no more than just enough to permit the water to enter freely. This is obtained by first inserting the pipe entirely into the bell, marking this position, and then drawing the pipe back ½ in. To prevent the entrance of soil into the pipe a layer of hay or straw is packed about the joints. It is also an advantage to line the sides of the trench with straw and the top of the filling should be similarly protected. The back-filling was at first of pebbles, later of old stone ballast, but is now usually of cinders and stone combined. Where the soil is very wet it will be found that cinders alone make the best filling.

Expedition Desirable.—When the drains are being applied it is desirable that the work be done expeditiously, to avoid

a rapid deterioration of the surface or a sudden bending out of the line. Where the cut is very bad it may be necessary to confine the work to short sections at a time, or in extreme cases to employ sheet piling. If the operation is conducted with care there is no essential danger connected with the work; but it is required that the placing of the pipe and at least a partial backfilling of the trench shall follow the excavation closely. In every case it is advisable to have all necessary materials close at hand before the operation is begun. It should be understood that the track will require additional maintenance for a period which may be as long as six months, because of the water in the roadbed finding outlets into the new drain.

Special Equipment.—With a narrow-gage railway and an equipment of two dump cars, holding 1⅓ cu. yd. each, the excavated soil can be moved to the end of the cut with one car, and the material for back-filling brought in with the other car, these to be alternated in the two operations. A turnout and spur is required in the narrow-gage track at the end of the cut. Since the width of the excavated trench is 18 in. and its depth 42 in. it will be found that a car of filling material is required for each 200 ft. of length.

Pipe Drains on the Sante Fe.—A system of tile drainage, which has points of similarity to the method described, has been in use on the Atchison, Topeka and Sante Fe for about five years. The slope of the cut is produced down to a point



Cross Section of Roadbed Laid with Pipe Lateral Drains

5 ft. below the base of rail to form one side of the ditch, in which the main tile, of 8 in. diameter or larger, is laid. The other side of the ditch is formed by a plane extending from the top of the tie at its outer end on a slope of approximately

one to one to an intersection with the bottom of the ditch. This produces a trench about 3 ft. deep, 1 ft. wide at the bottom and 7 ft. wide at the top.

In this trench is laid the main tile of vitrified, bell-end pipe. Connected to the main by means of tees are 4-in. laterals, spaced half a rail length apart, and extending usually to a point between the outer rail and the center of the track, being so laid as to tap the water pockets in the roadbed. In most cases a line of tile is laid on each side of the roadbed and the laterals are then staggered so that a lateral occurs every 8¼ ft. The main trench is back-filled with cinders, while the laterals are surrounded with either stone, gravel or cinder.

Economy of Tile Drains.—The performance of these systems of drains has been satisfactory in every way. The water drained from the roadbed in a considerable amount for long periods after rainfall has ceased, and in moderate quantity even in dry weather, furnishes concrete evidence that economy of maintenance is being conserved. While the cost of these systems is an item to be considered, the results attained in providing a better and safer track at reduced expense fully justify the investment.

The question will not infrequently be presented as to the propriety of placing these drains on a single- or double-track road which is in time to be laid with additional tracks. The answer is that such a betterment is always in order. While in the case illustrated a saving of one-half in the cost of maintenance was effected, there are places where a saving of nine-tenths is thus accomplished. The drain might in such cases be laid a few inches closer to the existing track, so that it would lie in the center line between tracks when the addition was made.

There are in addition points where longitudinal drains have been laid along the center line between tracks with good results, 3,500 ft. of such drains being in place at three points on the division referred to. It is preferable in such cases to use the 8-in. size of pipe. The portion of the drain that leads beneath the outside tracks should be laid with iron pipe in place of terra cotta.

15. Draining Embankments.

Cause of Pockets in Fills.—In the study of water pockets in embankments there is usually present the element of safety to traffic as well as economy in maintenance. Disastrous slips of embankments have occurred even on roads that were comparatively old. A case is known in which many miles of an important trunk line were put out of service following a 10-day period of continuous rainfall.

The cause of pockets in fills is not infrequently the use of a light material at certain places in the midst of a heavier material. More often, however, it is the direct result of the short-sighted policy of imposing a fast and heavy traffic upon a new embankment with only cinder ballast, and sometimes a poor quality of that, to distribute the load. The natural result is that the section lying just beneath the ties is compressed by the traffic, and this space eventually becomes composed wholly of cinder, the most pervious of all materials, and remains surrounded by the much less porous materials of the original fill.

Such a condition seldom develops when the new tracks are at once laid in stone ballast, or are thus equipped before the pockets have been formed. The author knows of two specific instances in which the early placing of stone ballast resulted in avoidance of this disadvantage. The entire uniformity in the subsequent maintenance throughout the new lines furnished undoubted proof that pockets were nowhere created.

French Drains Most Effective.—When constant attention is necessary at any particular spot to maintain the surface, the cause almost always is the presence of a water pocket. Economy in repairs requires that the trouble shall be corrected without delay. By reason of the continual change occurring in fills, pipe drains are not usually practical, and French drains, which are blind drains filled with various sizes of stone, prove much more effective.

Method of Placing Drain.—A trench to receive the drain is first cut into the side of the embankment leading upward to the bottom of the pockets, or in special cases is cut entirely through the fill. The trench is made of sufficient size to drain the cavity, and is usually from 2 to 3 ft. in width and at least 5 ft. deep below the base of rail. One-man stone is

proper for filling the bulk of the drain; but it is sometimes an advantage to encompass the larger stone with broken stone of ballast size to serve as a filter for the surrounding soil. Care should be taken that a sufficient fall is provided, so that subsequent settling of the embankment will still leave a practical grade. If a considerable flow of water is caused, a paved gutter may be necessary to lead the stream down the embankment without erosion. When the embankments are low and the adjacent ground flat, a longitudinal drain may be required to receive and carry away the water. Pipe is not always practicable, and for this also, resort to a French drain may be necessary.

Example of a French Drain Installed in Fill.—The photograph shows a French drain being installed in an embank-

Installing a French Drain in Fill

ment on the New York to Washington line of the Pennsylvania. The water pocket had its axis across the roadway at an angle of 60 deg. with the center line. The stretch of

road affected by the pocket was 50 ft. in length and included six joints which required tamping every few days; the placing of this drain has entirely cured the trouble from the water pockets. The detailed method of shoring the trench may be seen in the photograph. The vertical shores are in sections so as to be readily knocked down and removed at the moment the stone filing is to be applied. Short laterals also were placed in the center ditch to enlarge the scope of the drain. The cost of installing this drain was $200, which, however, included no charge for the two cars of one-man stone used, as they were wasted from another operation.

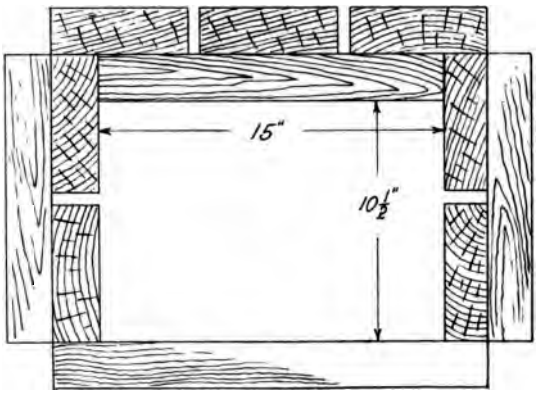
16. Draining Level Stretches.

Red Shale Bottom.—In many parts of this country are found deposits of a red shale which becomes quite hard when dry, but puddles quickly when water is present. This soil, when forming the roadbed of a railroad carrying heavy or fast traffic, causes much trouble at every heavy rain or long continued period of moderate showers. This was especially the case on the New York division of the Pennsylvania through portions of the State of New Jersey. The speed over this line is exceptionally high, a uniform rate of 70 miles per hour being generally maintained. At such a fast rate it is essential that joints as low as ¼ in. be kept as few as possible. The former method of coping with the pumping track was to dig out the ballast the moment the red mud made its appearance. This was not only expensive of labor, but the road was rendered unsightly in places by the piles of red clay awaiting loading.

Cinder Sub-Bed Temporarily Useful.—It was felt that if the water could be intercepted before it reached the clay soil relief would be obtained. The experiment was tried of raising the track to provide a blanket of cinder between the ballast and the clay bed. This was effective for a time, but as soon as the cinder became impregnated with the clay, which was in about two years, the trouble reappeared. It was then suggested that longitudinal drainage be obtained along the center line between tracks. Pipe was considered, but it was concluded that sufficient entrance for the water could not be had through the joints alone.

Wooden Box Drains.—A bottomless box 12½-in. by 15

in. interior cross-section was constructed of creosoted lumber. The 2-in. by 6-in. planks forming the box were separated ½ in., and the sides were bored with many ½-in. holes. The



Cross Section of Wooden Box

box was placed just below the sub-grade, which was 18 in. below the bottom of the tie. The box was then on the same level with the 12-in. cushion of cinders, and received mainly the water that seeped through the ballast and cinders, which was thus drained away before it had the chance of puddling the red shale sub-bed. A considerable stream was thereby collected which was discharged at proper intervals beneath the outer tracks into the side ditches.

Cleaning the Drain.—Generally no attempt was made to obtain a greater fall for the drains than the grade of the road, which varies from level to 0.6 per cent. Where the grade is no less than 0.5 per cent the drain is fairly self-cleaning. For lower gradients it becomes necessary to clean the drain, which is done in the winter while the track is frozen and other work is not so pressing. To facilitate this the top of the box is made removable. The 15-in. width of the box permits of a shovel working to advantage between the sides, the dirt being loaded directly upon the work train. This system of drainage has given good results through a period of about 10 years.

17. Draining Yards

French Drain Between Tracks.—By reason of the lesser degree of maintenance practicable in yard tracks, the matter of drainage is of almost as much importance as upon main-line tracks. The presence of water at switches is a prolific source of accident. At certain places French drains have been laid parallel with the ladder track and afforded good results in drainage. It is occasionally necessary to build French drains between the tracks in a yard, in which case it is desirable to use ballast sizes for the top layer to avoid possible injury to trainmen.

Sump Holes at Switches.—In one case, that of a yard used largely for passenger drill movements, no other scheme of drainage was possible than sump holes. These were placed contiguous to the switches and were about 8 ft. deep and 5 ft. in diameter. Care was taken to have the top of the stone filling of ballast size. Where entrance to a storm sewer is practicable a system of tile drainage for yards is justified, even though a considerable first cost may be necessary.

18. Underdraining Sodded Banks.

Cinder-Filled Trenches Useful.—It has become a rather

Sodded Slopes Protected by Cinder Underdrains

common practice to sod the slopes of cuts, both on new construction and along old roadbeds. Where springs occur in the slopes there is often considerable difficulty in getting the sod to remain in place. Not only is the frequent slipping of the new sod a source of expense, but the bare spots mar the appearance of the remainder of the slopes. The remedy is found in a scheme for leading the water to the track ditches. This can be done most simply by means of cinder-filled trenches just beneath the sub-soil. These may be in the form of the letter Y or W. Sometimes a W imposed upon a Y will furnish the proper design for the leaders. They seldom need to be of greater cross-section than 18 in. square, and a 12-in. depth of soil covering the drains is sufficient for the cultivation of the sod.

CHAPTER IV

VEGETATION FOR BANKS

19. Economy From Use of Vegetation

Extension of Use.—It is only within the past 20 years that certain of the larger railway systems have determined upon a policy of encouraging the growth of vegetation upon the slopes of cuts, and within a still shorter period, upon those of embankments. The results have been so marked that the practice has continued on those roads, and has extended to other smaller roads, and has even been employed on some, which, by reason of carrying no passenger traffic, were not specially concerned with the item of appearance. As may be observed, the standard sections of roadway of the Pennsylvania contain a notation that the slopes are to be sodded or covered with vines. This rule has been broadly carried out as allotments permitted, and it is now recognized as the definite purpose of the road to protect slopes with vegetation wherever possible.

Ditching Reduced.—A concrete illustration of the advantage resulting from a comprehensive employment of vegetation is furnished by the experience of the author on a main-line subdivision of the highest requirements. It was a remarkable fact, but one which could not be controverted, that no expense whatever was necessary for ditching, and the expense for policing was similarly negligible. The appearance of the banks was a matter of pride to the officials and presumably of satisfaction to the patrons. Although many of the cuts contained springs there were no slides anywhere, and no slips of the embankments occurred, even during heavy and long-continued rainfall. The protection consisted of practically all the different types of vegetation discussed herein.

Variety Desirable.—The economy of vegetation being recognized the only remaining question has to do with the

type which is most suitable for a particular location, due regard being had of course for the character of maintenance appertaining to the road. To aid in determining the question different varieties of vegetation are described in detail and the matters of soil, cultivation and relative expense are also noted. It is of course preferable that as many kinds of vegetation as possible be used, since there will thus be an agreeable diversity in the passing landscape. It is also desirable that whatever kind of growth is in place it shall be properly cared for. Unkempt banks are less pleasing than the bare earth. The cost of reasonable attention to the plants is not a large item in any event.

20. Sodding

Protection Against Slips.—Sodding the slopes of cuts is justified in certain cases, and is largely repaid by the saving

Sodding a Slope

in roadway cleaning alone, aside from the improved appearance of the right of way. In the case of embankments, there is the further advantage of protection obtained against accident, which may not be fully appreciated. Many maintenance officers have been concerned at some time with the upkeep

of a new line. These men appreciate fully the danger that is inherent in a new fill, even a long time after it is put in. Only in those exceptional cases where the fill is entirely of rock is there complete security against slipping. The breaking of a new embankment, constructed wholly of gravel, during a heavy fall of rain lasting only an hour, which resulted in temporary discontinuance of service on the nearest track, is within the recent experience of the author. Sodding of the slopes of the new embankment was then in progress and the completion of this work at the point that failed furnished entire protection against further slipping. As the benefits that may be expected from sodding were fully illustrated in this one operation, it will be instructive to review the work briefly.

Sodding on a New Line.—The piece of road in question is part of a main line carrying a daily traffic of 200 trains. Although the height of the fill averaged 22 ft. for more than three miles, service was inaugurated at a speed of 30 miles per hour, which was increased after 36 hours to 50 miles per hour, and after one month to 70 miles per hour. The original grading was purposely made wide to provide for the erosion that was expected to occur through the winter, the shoulder of the fill being uniformly 9 ft. from the gage line. By the middle of the succeeding spring it was found that money was available for sodding, and this work was prosecuted through the entire summer and fall until a total of 10 acres had been laid. This was possible during the months of July and August, which were very hot and almost rainless, by reason of an unlimited quantity of water being available through the fire hydrants of the city. The sod was all cut from company ground, although one-half of it had to be shipped from a point 15 miles distant. It was cut in 12-in. squares and was handled flat, experience having shown that the percentage of breakage is greater when the sod is cut of a larger dimension or when it is rolled. A sod cutter, which ordinarily effects a saving of two-thirds the labor of cutting by hand, was not available for this operation.

Applying the Top Soil.—The gravel of the fill contained very little loam and it was necessary to apply a covering of top soil. The considerable length of the slope, 40 ft. at the

average depth, precluded the delivery of the top soil wholly from the bottom, although it was found practicable thus to supply the lower half of the slope. The upper half was supplied from cars, working upon the nearer tracks, which at that point were those assigned to passenger traffic, but whose use could be obtained at proper times. By reason of the great amount of top soil required, and in order to occupy the main tracks as little as possible, a minimum thickness was decided upon which was generally 2½ in. This depth proved to be a good choice as practically none of the sod was lost through slipping although no pegging or other support was given.

Placing and Caring for the Sod.—The sod was well rammed as laid and the watering through a 2½-in. hose was done without force. A small area was lost during a heavy downpour of rain the spring following, but this occurred where a 12-in. depth of soil had been used in filling up a depression in the slope. It is quite probable that if the top soil had been applied of a much greater thickness than 2½-in., there would have been extensive slipping. The need of fertilization for so thin a mold was not overlooked, and the entire area was plentifully sprinkled with bone meal the spring succeeding the sodding, care being then taken to afford the slope receiving the direct rays of the sun the greater advantage in this respect.

Expense of the Sodding.—A careful account of the expense of this sodding, as well as that for an equal amount at another point, gave 1½ cts. per sq. ft. as the average cost of the sod in place. The regrading of the slopes and the addition of the top soil made the average cost of the finished work $1,000 per acre, or about 2⅓ cts. per square ft. (These costs at the present price of labor would need to be increased to three times the figures given.) The total expenditure of $10,000 for sodding upon this one operation was warranted alone by the greater security against accident. The cost of mowing the banks, which is neecssary about four times during the season, is $25 per acre at each cutting; but this is no more than the periodical regrading of the banks on account of erosion would have cost. There is the further item of

attractiveness through the enhanced beauty of the roadway, which is not measurable.

21. Stimulating Growth With Street Dirt

Application of the Compost.—There are many slopes, especially in cuts, where the expense of sodding is not justified or this method is impracticable, but where, both for appearance and stability, a turf is desirable. It will be a matter of surprise to those who are unacquainted with the efficacy of street dirt fertilization to observe the quick growth which may be obtained by its use. A good turf has been developed in six months, a firm one in a year, and two years produces the equivalent of an old sod.

Formula for Sowing.—There are certain important points which must be observed in the use of this compost. On account of its lightness the material is easily washed away, and the best results are obtained by applying it after the spring rains are over. If sown with eight bushels to the acre of the mixture given below, an application of the material about June 1 should produce a turf by the middle of September that would ordinarily be proof against the fall rains:

Awnless brome grass	1 bushel
Canadian blue grass	1 bushel
Orchard grass	1 bushel
Herd's grass	1 bushel
Turkestan alfalfa clover	1 peck

Cheapness of the Method.—Street dirt should not be applied too thickly upon banks. A layer generally 2½ in. deep after all paper and other waste has been taken from it is the most favorable. It is not necessary to regrade the eroded surface of a bank before the street dirt is applied, and this fact alone recommends the method where cheapness is a governing requirement. It may be spread as late as the middle of October, but after that time is apt to be mostly dead leaves and should be allowed to rot in a pile over the winter to be ready for use in the spring.

Effectiveness of Street Dirt.—Besides its cheapness this method has been known to develop a growth when other means have failed. There are cuts upon whose slopes sodding has been vainly tried with every known precaution

observed, but which have responded to persistent applications of street dirt plentifully sown with the above mixture. The material may be obtained from contractors for street cleaning in any of the larger cities, loaded upon cars without cost.

22. Honeysuckle

The Woodbine Variety.—There are many varieties of this prolific vine, but the only one of concern in this connection is that which trains along the ground and is commonly known as woodbine. The woodbine may be grown in any soil either from the root or a cutting. It takes root wherever it touches the ground, provided the soil is not too hard. In that event it will not spread, but will grow up bushy. The best results are had by planting in March either the roots or sections of the vines, set five or six feet apart, or closer if a mat is desired more quickly. It grows slowly the first year but faster thereafter, and will cover the ground in about three years.

Usefulness of the Growth.—When the mat of honeysuckle is fully formed it will resist any wash, and is thus superior to sod for preventing unstable soils washing down into the ditches. As a means of retaining a steep slope necessary by reason of insufficient property, it is of unequaled utility. The vine blooms profusely in the early spring and continues a moderate flowering late into the autumn. Its blossom is very fragrant and the odor may be caught on passing trains.

Mowing the Vines.—Honeysuckle does not require mowing until the growth becomes thick and the plants high and full of dead wood. This only occurs at long intervals, and there is thus practically no expense for cutting. It should never be mowed while in bloom, as there is danger of the vines being killed. If necessary at all it may be done at the second mowing of the year, when the growth should be cut to within 6 in. of the ground. As these plants retain their moisture late, there is small likelihood of fires starting in them.

23. Roses

Rugosa, Humilis and Wichuriana.—There are several varieties of summer and autumn flowering perpetual briar roses which, by reason of their dwarf habits and their wide and

deep rooting characteristics, form an excellent means of protecting the slopes both of cuts and embankments, besides supplying the element of beauty which helps to make travel agreeable. The R. Rugosa, or Japan rose, has been much employed upon both kinds of slopes, but on account of its somewhat irregular growth is apt to convey an impression of neglect and is somewhat better suited to fills where its holding advantages alone prevail. The R. Humilis or Lucida, which seldom grows higher than 18 in. and tends more toward uniformity of growth, is the preferable variety for use upon the slopes of cuts since it always presents the appearance of being cultivated even though no care is actually required. The R. Wichuriana, or Memorial rose, a half evergreen shrub with prostrate and creeping branches, and one of the hardiest of trailing perpetual briars, makes a handsome covering for banks, but does not have as great holding power as the two other roses named.

Cultivation of the Roses.—These plants are exceptionally hardy and may be grown anywhere between Maine and Florida. Their foliage is nearly evergreen, but quite late in the fall the leaves turn purple, orange and yellow, and they bear a red berry which gives the plant an exceedingly attractive appearance at all times. Like all roses they may be grown in almost any kind of soil except a very loose and sandy one and require little cultivation. They should be set out in the early spring, from 2 to 3 ft. apart and as deep as in the hot house mold. A light covering of street dirt is effective when the growth is being started.

Propagation.—These roses can be propagated by seeds, but they may also be grown readily in summer under glass from cuttings of nearly ripened wood. A single plant will furnish in several seasons as many as 500 cuttings. The abhorrence of all roses for continual dampness is well known, and their cultivation on wet slopes is therefore not practicable. The New England roads have many miles of roadway planted with roses, and the Pennsylvania has been using this protection with success for several years.

24. Alfalfa

Fertile Soil Required.—This hardiest of perennial forage

plants is cultivated in the most diverse localities, but is especially adapted to land that is neither low lying nor extreme in altitude. It has a large tap root with very few side roots. Its extreme penetrating power renders it a valuable protection against ultimate slipping of the banks, but the time required for developing its hardiest growth makes it a somewhat better selection for older banks. It can only be grown in a fertile soil and the best results are had by developing this feature the year preceding the alfalfa seeding. Common fertilizer will produce a growth of weeds which must be destroyed before they reseed, as these greatly impede the growth of the plant. It is even desirable to cut the first crop of alfalfa early before the weeds have had a chance to reseed. In fact, as full development cannot be expected until the third year, the principal aim in the meantime should be to eradicate the weeds. After a full growth has been established no further cultivation is necessary.

Clay Sub-Soils Favorable.—For the best results the top soil should be light and not sandy, and the soil should be a clayey loam. It is desirable that the sub-soil also be of a clayey nature, as this will retain the moisture needed by the plant in the drier seasons. The thorough surface drainage required for its cultivation is afforded naturally by the contour of the slopes; but the ground above or below the slopes needs to have the depressions filled, since the plant will not thrive in marshy ground. A gumbo element in the soil if properly cultivated is not objectionable. Farm manure should be worked into such soil to lighten it, and render it permeable to air and water.

Inoculating Soil Not Essential.—It is usually thought that inoculating soil is necessary for the cultivation of alfalfa. Doubtless such addition is an advantage and its use is recommended where it can be conveniently obtained either from soils in which the plant has been grown or commercially. However, good results have been obtained without any inoculation. This plant is a prolific seed producer and no expense is necessary for further seeding. It is favorite food for all sorts of stock and it is seldom difficult to command the services of adjoining farmers to harvest the slopes for the

hay obtained. As many as six cuttings may be made in a season.

Rye for Supplementary Sowing.—Alfalfa dies to the surface of the ground in the late fall and is thus apt to leave the slopes bare. This objection may be overcome by sowing rye in the fall, which will keep the slopes green until the next spring. The plant has been successfully cultivated for a roadway protection upon the slopes of embankments throughout the low-lying lands of the Atlantic seacoast.

25. Occasional Grasses and Sedges.

Bermuda Grass.—There are other plants which have been found useful for holding embankments, but which are of somewhat less common application. Bermuda grass ranks high as one of the turf-forming grasses. It is cultivated extensively in the southern states, but is generally distributed over the warmer portion of the United States. It does not thrive in the more northerly districts, which are subject to long continued periods of dry weather, except where the means is available for plentiful watering. This grass spreads freely by creeping root stocks, and like the grasses in general, requires good drainage. Where appearance is an important consideration, June grass should be mixed with it. These supplement each other in different kinds of weather and assure a green bank during every part of the growing season. The other grasses that have good binding qualities are quack grass, Rhode Island bent and red top.

Irish Heath.—Irish Heath is one of the sedges that has been used with greater or less success for holding the slopes of cuts. It is an evergreen plant and bears a small purple or white flower. It is propagated by seeds or cuttings and thrives best in peaty, sandy soils. Protection must be afforded the plant during the winter in the northern part of the United States. Slopes along the Pennsylvania have had the protection of the plant for a period of 15 years, and while the growth is quite satisfactory when established, its development is somewhat tedious.

26. Dwarf Trees

Pines, Spruces and Willows.—Practical use may be made of certain varieties of the pines, spruces and willows for

planting on steep banks and slopes, especially those subject to slipping. The Austrian pine, the Norway spruce and the yellow-barked willows are the most suitable for bank protection. All three plants are hardy throughout the temperate zone. The pines are especially adapted to high altitudes where cold bleak winds prevail. The spruces are preferred where a rapid growing plant is desired. The willows do not, as is popularly supposed, require the proximity of streams, but thrive very well remote from water. They have all demonstrated their usefulness in holding banks, and are often effective where other means have failed.

Usefulness for Snow Breaks.—They each likewise serve the useful purpose of arresting the progress of drifting snow.

Spruces Used for Snow Breaks

Evergreen snow fences are becoming common, especially on the more northerly roads, where snow forms a continual

menace in the winter time. The spruces are most frequently employed by reason of their more rapid and uniform growth. They are set out when 3 ft. high and grow to a height of 9 ft. in about 6 years. They are then trimmed down and kept at this height. The hedge row is established 75 ft. from the nearest track. The plants are set about 2 ft. apart and as deep as in their natural bed, care being required that the moisture in the roots shall not be lost in transplanting. Protection against fires is obtained by keeping dead grass removed from about the trees. The California privet is somewhat similarly employed for snow breaks, and its cultivation and protection are practically the same as those of the spruce.

CHAPTER V

LABOR SAVING DEVICES AND METHODS IN ROADWAY WORK

27. Distributing Operations

The Work Train an Essential Force.—There is on many supervisors' divisions a deplorable lack of train distributing facilities. The work train is without doubt the most important force in the supervisor's department. On branch divisions especially, much labor is wasted through section foremen being compelled to truck their material for ordinary renewals over long distances. In some places this is partially met by the use of pick-up trains, but this is not wholly satisfactory. Regular work train assignment, even though it is only for a part of the time, is much preferable.

Heating the Riding Car.—Some work trains have full provision for heating the riding car at all times. This is of particular use in the drying of damp clothes, and has its effect in a greater efficiency of the men. One work train has an Eastman heater with ample system of radiating pipes. Another has a large hoop concentric with the stove and about two feet above it, with hooks for hanging up the wet clothes. Provision of raincoats, slickers and gum boots is made for the entire force on wreck trains and this practice well may be extended to include work trains also. The foreman should see to it that the men put on the garments before their regular clothes become saturated. A moderate commissary is a useful equipment for work trains, as well as for wreck trains. Emergency repairs not infrequently take the train force to isolated points, and even a light lunch may suffice to complete such work.

Steam Derricks.—Where a rail loader is not available, or the work in hand is beyond its scope, a small steam derrick can be carried with the train and perform efficient service, not only in unloading rails, but in handling heavy frogs, tele-

graph poles, concrete pipe, etc. Nearly all the common types of ditching machines may be quickly changed to a locomotive crane on occasion, and thus avoid the need of carrying an additional car where both ditching and crane work are required.

Clam Shell and Drag Line Buckets.—Locomotive cranes are also of use when equipped with a clam shell bucket or a drag line scraper to perform many digging operations which are of a different character to that of the ordinary ditching work. In making any rectangular excavation, a clam shell will effect a large saving of labor. The clam shell is useful also in transferring lading in bulk from open top equipment. When the grading desired is beyond reach of the dipper arm, the drag line excavator is a useful equipment.

Work Train Accessories.—A common deficiency of nearly all work trains is a device to prevent dirt, which is being unloaded, from dropping upon the ballast. This is particularly necessary where cinder ballast is concerned. There is in use for this purpose an apron of canvas which answers very well the object of keeping the dirt out of the ballast. In the delivery of coal to stations a chute is in use by which the coal may be run directly into the bins, saving much labor over the basket method. It is made in sections to suit the different locations. Where the basket method must be used, there is a funnel attachment by which coal may be shoveled into the baskets held beneath.

Use of Buckets in Ditching.—When standard ditching is being done by work train a method is made use of to obtain the fullest possible service of the train. Buckets are provided which are filled while the train is absent and upon its return are lifted by derrick or rail loader upon the flats and similarly unloaded. When a fill is being made for a new track alongside an operated track whose use cannot readily be had, it is economical to establish a temporary grade several feet below the final grade, using the material of the shoulder for the purpose. The track can then be laid and connected up and the material as it becomes available be dumped directly into the new track without interference.

The lifting of the track can be done most cheaply by the use of the steam derrick.

Proper Types of Cars for Ballast.—A great saving in the cost of unloading ballast is effected by having the ballast supplied in proper cars. Specially designed ballast cars are efficient because the ballast may be dumped in more nearly uniform quantity. If C. T. service cars only are available, the hopper bottom type should be used where train service permits occupation of the track to be ballasted. Where congestion of the passenger tracks prevents their use by work trains, flat-bottom gondola cars are most efficient for ballast needed in these tracks; while the flat bottom cars with pockets are quite satisfactory if a combination of dumping and shoveling is practicable.

Power Devices in Reballasting.—In a continuous operation of replacing cinder or gravel ballast with stone, where the old material is to be taken away, a power ditching machine is desirable. With its use the cost of loading the old ballast is lessened fully one-third. The cost of the work can be reduced $1,000 per mile of double track and the cost of such a machine will be saved in renewing ten miles of line.

A Section Gang on a Motor Car

Hand Cars and Motor Cars.—In the distribution of men, where local trains are available at convenient times, they furnish the best means of transporting them from their homes to the subdivision headquarters; but hand cars are still required to carry the men and tools to the places of work. When this distance is over five miles, a power car becomes desirable. Motor cars, making 15 miles per hour as against about 9 made by hand cars under average conditions, are very efficient. The saving by this equipment where 16 men are transported 7 miles each way is equivalent to the labor of one man.

28. Picking Up Scrap

Saturday for Collecting.—No system of scrap reclamation furnishes the desired results that is not automatic and routine. On many roads the rule is in force that Saturday, whether it be the entire working day or the short day, that is more common, is given over to policing and the general cleaning of the roadbed, which includes the collecting of small scrap. Every tool house is provided with a bin where this small material is to be stored; but not infrequently the Saturday's collection lies in the center ditch awaiting a convenient time for trucking it to the section headquarters. If the supervisor were equipped to run a train over his division every Saturday afternoon this unsightly material might be disposed of at once; but the considerable time required for hand loading necessarily postpones the collection.

Loading With Crane.—There is in use at many shops a type of locomotive crane with magnet, generator and switchboard, which handles small scrap quickly and with a minimum of expense. This machine requires only the attendance of one man and the cost of loading the scrap at the shop has been found to be as low as three cents per ton. The cost would of course be very much greater for loading it along the road; but with average opportunity to work would probably be no more than 20 cents per ton. Such a contrivance run special over the road every Saturday would result in a clean division for the holiday travel, and would bring the scrap under the eye of the proper authority.

29. General Cleaning

Disposing of Grass and Weeds.—For the cutting and burning of grass and weeds there are several new labor-saving devices. Motor car mowing machines and disc weeding machines have demonstrated their practical utility. Where the right of way is wide and its surface flat it is sometimes practicable to make use of the common farm reaper, and indeed it is often possible to have the grass cut by this method by the adjoining farmer with moderate expense to the Company. To avoid the unfavorable appearance of the roadway from burning grass in piles upon it, or alternately to save the considerable expense of mowing and loading up the grass, weed burners have been used at several points with good results. Oiling the shoulder not only minimizes the dust, but retards the growth of weeds as well. Weed killers have proved effective in destroying the grass in the ballast and shoulder, but are dangerous to cattle.

Cleaning Delivery Yards.—In removing dirt from delivery yards, it has been found to be economical to employ teams, hauling the material to a dump, rather than work trains which are liable to serious delays while so engaged and in turn introduce more or less interruption to the business of the yard. In certain congested districts the periodical cleaning of the roadway can best be done on Sundays, half the labor being sometimes saved by this arrangement.

Policing by Special-Duty Men.—Where appearance is a matter of consequence, as in residential districts, or in large delivery yards, especially in strongly competitive territory, or generally at the approach to the more important stations, the most efficient method of keeping the property clean is to employ one or more special-duty men, whose entire time is devoted to picking up the waste paper and other rubbish. A necessary equipment for such employe is a commodious bag and a stick with a sharp wire nail inserted in the end. When heavier articles are to be gathered up in yards, such as lumps of coal, cinders, or scrap, a push cart, consisting of a wood or sheet iron box on a pair of old hand car wheels, is quite useful.

30. Cleaning Snow and Ice

Usual Methods Employed.—The common method of removing snow and ice is by hand labor with shovels and with brooms provided with scraper handles. Every division has one or more snow plows which can be attached quickly to the pilot or front bumper beam of a locomotive. M. W. box cars, equipped with snow flangers, are assigned to certain points on the divisions, and flangers are also supplied, which are attached just behind the engine pilots. Snow boards are applied to the pilots of all passenger locomotives at the approach of winter and kept on until spring. Push scrapers are in general use for scraping the snow on platforms into piles.

Snow Plows.—Many roads are equipped with snow plows which are box cars of substantial construction with the entire front end shaped as a plow. They are formed to raise the snow four or five feet and throw it to the sides. The single track plow is made to throw half the snow to each side, the double track plow to throw all to the right side. They are intended to be pushed by one or two locomotives and are equipped with a push pole whereby the thrust is transmitted to the plow just behind the cutting point. This helps greatly to avoid derailment when heavy snow is being bucked.

A desirable feature in a snow plow is a special truck for the front end, of heavy construction entirely without springs, and equipped with an extra set of journal bearings just inside the wheels. The absence of springs prevents the front of the plow being depressed by the snow and renders greater speed possible, and the double bearings avoid hot boxes at the higher speeds. The bit for plows is permanently set, usually 2 in. above the rail, and is as wide as the clearance in its territory will permit. Some plows are also equipped with a single or double-discharge flanger, operating in one direction of train movement. The flanger is not attached to the car trucks, but is supported from the under side of the car.

The double discharge plow will handle readily drifts as high as the car; the right hand plow drifts five or six feet high. A feature that is especially useful to the four-track

divisions is the wing elevation attachment. These wings consist of heavy wooden surfaces one on each side of the car which are about 12 ft. square. They are held in position by vertical pivots and are moved outward and inward by compressed air. With the wings in use the swath cut by the plow is 16 ft. wide, and the snow is thus thrown well clear of the track.

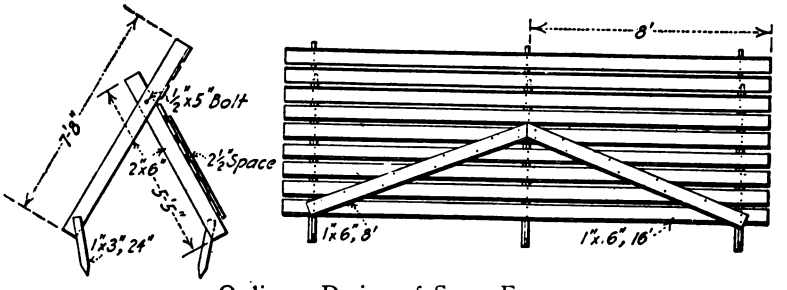
Spreader Cars.—Spreader cars are usually equipped for cleaning snow and ice from tracks and are highly efficient in this service. Certain of these cars are designed to push the snow 22 ft. from the center of the track and to a depth of 2 or more inches below the top of the rail. The operation of the cars by one man often avoids the need for employing a large force of men for clearing the road in a snow storm.

Snow Melting Oils.—The hydrocarbon and snow melting oils form efficient means of clearing snow and ice from switches, and are particularly effective in removing sleet from interlocking connections. The two oils are very similar and are volatile liquids comparable with gasoline. They are applied to the switches from hand distributing cans holding three gallons. These cans have a nose about three feet long made of ⅜-in. pipe with a valve. The end of the pipe has a hole 1/32 in. in diameter to let out the oil, and is wrapped with asbestos for several inches to form a sort of torch. The hand cans are filled from a large tank near the interlocking holding 150 gal.

Special Snow Equipment.—Somewhat less common equipment for handling snow and ice trouble are rotary plows, calcium chloride cars, and commissary cars. The rotary plow is necessary when the drifts exceed about 10 ft. in depth. At least two engines are usually required to keep the plow against the snow. The rotary is seldom able to make faster speed than five miles an hour when working against closely packed snow. Chloride cars are used to spread a solution of calcium chloride over the third rail in electrified sections. The fluid is distributed through a small hose by air pressure as the train progresses at a speed of about 10 miles an hour. The commissary is indispensable in sparsely settled districts where food may not surely be procured from local sources.

Melting Snow as It Falls.—Several devices are in use for decreasing the force required to handle snow at interlocking plants. A practical scheme for removing snow at interlocking switches by steam heat was devised at an important terminal. Pipes 2 in. in diameter, carrying live steam, were installed between every second tie under the moving parts of the switches and slips. The heat from ordinary illuminating gas burners has similarly been employed for melting snow. The jets are placed between the ties and shielded by a peaked roof of tin upon which the snow melts and, running down the sides, is drained away. There are pits at several points into which the snow is thrown as it is cleaned from the tracks. These pits are 8 ft. by 18 ft. by 20 ft. deep at one location. About 4 ft. from the bottom are heat pipes to melt the snow which then drains away to the city sewer. The trouble from ice forming along water troughs is treated in a special article on track maintenance at water stations.

Snow Fences.—The means of avoiding snow trouble form a labor saving element equally with economical methods of removing it. Snow breaks of evergreen trees were mentioned in the chapter on vegetation. The most common protection against drifting snow is the portable snow fence, which is set in place in the fall and usually removed and stored at the close of the winter. As ordinarily constructed the fence is in panels 16 ft. long, and is made of 1-in. by



Ordinary Design of Snow Fence

6-in. undressed lumber in horizontal rails placed 2½ in. apart. The rails are supported on 2-in. by 6-in. posts which slant to the lee of the wind and are held by similar posts which slant

against the wind at an equal angle. The latter posts are extended to carry three additional rails which form a hood to hold the snow long enough to break its force somewhat. The two sets of posts are held to the ground by stakes and all joints are made with bolts so the fence may be folded for convenient handling. Snow fences are generally 8 ft. in height and placed a practical distance from the track, which varies between 60 ft. and 100 ft.

Selecting the Locations.—On account of the usual need of leasing the privilege of maintaining a snow fence on private ground, which often will be at an exorbitant rental, it is necessary to determine by careful study where the protection is indispensable. This is generally facing narrow cuts where drifting snow would quickly obstruct the road, and always where an interlocking is located in a cut. The difficulty in maintaining divergent movements in severe snowstorms is large enough without being complicated with drifting snow. Consideration might well be given to the protection of points which are not altogether critical, but which, by reason of isolated situation, might become troublesome before adequate force could be assembled.

CHAPTER VI

ECONOMICS OF ROADWAY

31. General Recommendations

(With especial reference to improper practices.)

Selection of Right Methods Important.—There is no more fruitful source of error in roadway work than a wrong selection of the means for its performance. The matter has been studied in such detail that it is possible to establish working limits for all the various methods used in grading operations. In general, if the work is considerable and proper supervision available, machinery should always be employed. When the operation is small the work should be done by subdivision later; when of medium extent and so interlaced with other operations that no adequate unit of payment can be made, by force account; and if heavy and under all conditions of detail, by contract. The contract method is preferable for all extraordinary roadway operations when several competitive bids can be obtained.

Methods in Order of Availability.—Since certain of the more efficient means are not always to be had, the various types will necessarily overlap. The common methods, in the order of their availability are wheelbarrow, scraper, horse and cart, wagon, and power machinery, which includes motor trucks and tractors. The cost per yard of loading dirt with a steam shovel and of moving a yard of dirt by wheelbarrow or horse and cart within a radius of 100 ft. are about the same. When the radius is extended to 1,000 ft. the power method is twice as efficient as the cart; the cart twice as efficient as the scraper; the scraper twice as efficient as the wheelbarrow; or, the power method excels the wheelbarrow as 8 to 1. For all distances the horse and cart is twice as efficient as the scraper. The cart exceeds in efficiency the wheelbarrow for haul above 100 ft. in a regularly increasing ratio for enlarging field. Beyond 1,000 ft. the dump wagon

is more efficient than the horse and cart. When these means or power cannot be had, the choice will lie between wheelbarrow and scraper. Within the limits of 200 ft. the wheelbarrow is the more economical; beyond that distance the scraper is preferable. In any large work where the haul is more than one-half mile motor trucks with power diggers effect a saving of from two-thirds to three-fourths the labor of grading by hand methods.

Standard Ditching.—The largest single item of maintenance work outside of the regular repair of the roadway and track is standard ditching. About 20 years ago it was found that the development of a firmer track structure required that the side ditches should be deepened to furnish drainage not only for the roadbed proper, but for the sub-bed also. Standard sections of roadway then placed the slope of a cutting 10 ft. from the gage line at the level of the grade. Similar plans now require that it shall be 13 ft. The work of removing the surplus earth to provide this increased width has, except in a few instances, fallen to the lot of the track forces to perform at odd times, and although much has been completed, a great deal still remains to be done. The experience gained from past performance should work economy and method in future operations.

Disposing of the Dirt.—The simplest means of disposing of the dirt was to cast it upon the top of the bank, the only disadvantage being an increase in the height of the slope requiring somewhat greater expense for sodding or other protection. In the case of the four-track or greater-multiple track roads, which might reasonably be considered finished, the practice was a proper one. But as regards the one and two track stretches of road that are even now being widened to three or more tracks, with other similar extensions projected, the practice was not economical. In the grading for these additional facilities the dirt that was originally cast up, again required moving, and there was thus one handling of the material which constituted a dead loss. It may be alleged that the means was lacking at the time for handling this dirt in any other way. But the full benefit of the deeper ditch might for the time being have been obtained by cutting away only the toe of the slope on an angle of as little as 10 deg.

with the vertical and facing this with a single layer of Belgian blocks, which has held similar banks firm for many years.

Widening Fills for Future Extensions.—In widening cuts it is nearly always possible to waste the dirt upon adjacent fills, which are nowise disadvantaged thereby and the future extensions are thus being aided. This may be done most cheaply by the use of a narrow-gage railway and suitable cars, each holding from 1¼ to 1½ cu. yd., drawn by a horse or pushed by men as best accords with the local conditions. The length of track would only need to be a little longer than the cut to be widened, as it is equally advantageous to begin operation at the end most remote from the fill and as a section is graded to use the track that served that section for extending the railway along the fill. It is generally possible to waste what is taken from the cut upon a similar length of fill.

Buckets for Standard Ditching.—In the event that this equipment is unobtainable or the method not applicable and resort must be had to operating a work train, the most expensive means of all, it is worth while to study how to obtain greater use of the train, especially upon the single- or double-track roads and also upon the four-track systems where extended occupation of the outer tracks is impracticable. Much labor can be saved by having an equipment of buckets that may be distributed along the ditch and be filled by the labor force while the train is absent and upon its return picked up by the rail loader or derrick and unloaded by dropping the bottoms, using but a few men at the dump, while the remaining force continues the grading with other buckets.

Power Ditching Machines for General Cleaning.—When the standard ditching operation is large and reasonable use may be had of the tracks next to the ditches it is economical to use a power ditching machine of which there are several types on the market. The cost of the earthwork may be brought as low as 20c per yard including the disposal of the dirt. There are few grand divisions of any of the more important lines that would not be justified in adding to their permanent equipment one or the other of the ditchers. These should be supplemented with graders, unloaders and spreaders.

Economy of Machines for Deep Excavations.—It is not unusual for the track forces to be called upon to remove dirt from a considerable depth below the grade of the track with the means of disposing of this dirt by any hand method impracticable or possible only with much handling and at a great expense. In such cases it is the duty of those in charge of the power facilities for such operations to see to it that they are furnished. A case in point is the excavation for a retaining wall extending 30 ft. below the track which had to be loaded upon cars for disposal. The work was possible by hand, but it was apparent, upon the supplying of a derrick car and bucket, that three-fourths of the original labor had been wasted.

Old Tie Cribs.—It is sometimes necessary to provide a permanent artificial support for the roadway. When this occurs alongside a main track nothing but masonry should be considered. When the facility is a siding used at low speed, or a driveway or the parking at an unimportant station, a cribwork may be proper, both by reason of its cheapness and its availability. If properly built even of discarded ties such construction may last 20 years. Unless the thrust is great the design may be the opposite of that for a retaining wall, the width being about 3 ft. at the bottom and 8 ft. 6 in. at the top. The face may be vertical or on a batir of an inch to the foot. For greater stability the bottom courses should dip slightly toward the track to be supported. It is very important that as the construction proceeds all interstices should be carefully filled with soil to exclude the air as much as possible. Tie cribs should not be used for heights greater than 10 ft., as above that height masonry is not only safer, but in the long run more economical.

Economy of Proper Means and Methods.—The facilities needed for efficient performance of the smaller items or roadway are often lacking and the loss, while small in the single item, is large in the aggregate. In cleaning the center ditch the dirt is often carried to the sides to be spread on the slopes of a fill. It would be wasteful to do this by the shovelful when the work could be done so much more cheaply, and at the same time more safely, with hand barrows. A satisfactory barrow can be made by nailing two strips to a half barrel; but

rectangular boxes of sheet iron or wood are more commonly furnished. In a small grading operation the use of boxes when wheelbarrows are proper, or the use of wheel barrows when the length of haul would warrant the employment of a horse and cart, are items of waste that are sometimes due to a short-sighted policy on the part of the maintenance officer. For conserving labor he well may see to it that tools and appliances are furnished which are best adapted to the work.

CHAPTER VII

TOOLS AND THEIR USES

32. The Track Jack, Level and Gage.

The Track Jack.—The track jack is the tool which is most often misused by the section forces. Its main function is to make considerable lifts of the track, the lighter surfacing, in which class are included lifts of not more than 2 in., being done preferably with the raising bar. An occasional use of the track jack is for lining track which is too heavy to be thrown with bars or where an adequate force for that purpose is not available. The jack should not be overstrained in either operation.

Jacks are of two kinds, single acting, in which the jack operates on the downward stroke only, and double acting, in which the jack operates on both the upward and downward strokes. They each are of two types, automatic lowering, when the load is lowered by the same movement through which it is raised; and lowering by tripping, when the load is raised and allowed to fall by releasing the pawl. The section jack is usually of the double-acting trip pattern.

When the jack is used for its proper object of raising the rail, there is frequently a lack of care in setting it, which entails extra work for lining after the raise is completed. Unless it is placed close to the rail and on a level bed so as to stand vertical, the track will be pushed out of line. It should never be used on the inside of the rail except when this is unavoidable, as sometimes is the case when switch connections are being raised, and then the use should be protected.

When the jack is set the handle should be removed at once and the trip catch thrown over to engage the lowering pin. The first is required to avoid any chance of its being struck by a train and the second so that the moment a train comes in sight the jack can be lowered and removed. The jack should not be thrown carelessly into the dirt, but pains should

be taken to keep it clean. It should also be oiled as may be necessary. The various parts of a jack are replaceable and it should not be discarded when a new part would restore it to working order. A well equipped main line section force should have four jacks as part of its tool equipment.

The Level.—The track level is merely a straight edge carrying a spirit level with the means provided for measuring superelevation. This may be done through a series of steps in the underside of the straight edge, or by a movable pawl. It is usually arranged to measure difference of elevation to the nearest ¼ in. The second means is the best, because when once set it indicates the elevation absolutely; while by the first method there is a chance that the wrong step may be used at times. It is important that the track level be kept in correct adjustment and a set screw is usually attached for keeping the level true. When this is lacking the alternative is to score new marks across the glass to indicate the position of the bubble when the level shows correctly.

The Gage.—The gage of track is the distance between the heads of the rails, measured at right angles at a point ⅝ in. below the top of the rails. For standard gage this distance is 4 ft. 8½ in. The track gage is a tool for measuring this distance when the rails are being brought to their correct positions with respect to each other. One end of the gage is usually shaped like a two-pronged fork to aid in placing it at right angles with the track. The two points of contact on this end, and the one point on the other end, are so adjusted that they will be ⅝ in. below the top of the rail when the gage is in position. When the track is being brought to standard gage, the rail should be held to the gage by a bar while the spike is being driven. The gage should never be used to spring the rails apart while correcting a tight gage. The tool should be tested periodically upon a standard kept at the subdivision headquarters, as explained elsewhere.

The Guard Rail Gage.—There is usually added to the track gage on the reverse side lugs which serve to measure the guard rail gage. This is the distance from the gage line of the frog to the flange side of the guard rail. It is also measured ⅝ in. below the top of the rail and its length is 4 ft. 6¾ in. This distance should be preserved even though the

gage of the track may vary from the standard. The error should not be made of changing the measure of the track gage and thereby destroying the accuracy of the guard rail gage when the two are in combination.

33. The Adz and Rail Cutter

The Adz.—These two simple tools are described because of the numerous accidents which result from their misuse. The adz is a cutting tool and needs to be kept sharp. It is useful for dressing the surface of the tie to provide an even bearing for the base of the rail or for the tie plate. It must sometimes be used to cut away the wood about the spikes to facilitate their removal. While renewal of crossings is properly the work of carpenters, such repairs are often the duty of the track force and in such repairs the adz is of frequent use. It is also used to cut off tie plugs applied when rails are being relaid or regaged. The man who is doing adzing should never stand straddling the rail, as the adz is liable to strike the rail and glance off, cutting his foot or ankle. It is also likely to be broken in thus hitting the rail. The man should stand with one foot on the rail and cut directly beneath the rail, lengthwise of the tie. The butts of old spikes should be driven down so the cutting edge will not be injured. The adz should not be left lying around where a fellow workman may fall over it.

The Rail Cutter.—The rail cutter is used to cut rails by being held in place while the top is struck by a sledge. The tempering of the steel in the rail cutter is very important, as otherwise it will wear out after a few blows. There is also the danger that pieces of steel may be broken off and fly into the eyes. The cutter should be redressed when it begins to broom, as the loss of eyesight is too serious to incur such a risk. There is the added danger that the striking hammer may fly off its handle and injure or possibly kill someone. To avoid this the man striking should face along the rail, while the man holding the cutter faces at right angles across the rail. It is sometimes necessary to cut a nut with the rail cutter while other men are working near by. They should be required to get out of the way, as the nut is apt to fly with great force. The foreman should watch very

carefully the condition of the cutters, the attachment of the striking hammers, and the manner in which both the adz and the cutter are used.

34. Tie Tongs and Rail Tongs

Tie Tongs.—Tie tongs should be so light that one man can use them readily, about 10 lb. being their usual weight. Their purpose is mainly to draw the new ties into place in the track. The pick should not be used for this purpose, especially with treated ties. The pick point will penetrate the treated section and allow water to enter, thus causing decay. The tie tongs are also used in carrying ties. When treated ties touch any part of the skin they are likely to cause a local irritation, which becomes troublesome if conveyed to the eyes. In the absence of the tongs gloves should be worn while carrying such ties.

Rail Tongs.—The rail tongs are somewhat heavier than the tie tongs, weighing about 16 lb. They are used by men working in pairs. A common misuse of the rail tongs is to attempt to carry a switch rail by holding to the tapering ball of the rail. The point is liable to slip from the tongs and fall upon the feet. The switch rail should be held by the base. When men are carrying a rail with the tongs each should be in a position to see where he is walking, as many injuries, some of a serious nature, result from neglect of this precaution.

Enough men should always be used to carry a rail without strain. This number is 12 for 85-lb., 14 for 100-lb. and 18 for 130-lb., 33-ft. rails. Rails are sometimes carried by means of bars stuck through the bolt holes, but this practice is unsafe for the men and injurious to the rails. Another practice that should not be permitted is the carrying of a piece of rail by means of the rail forks engaging the base of the upturned rail. The rail should only be carried by the rail tongs gripping the head in the proper way.

35. Hand Cars and Trucks and Pony Cars

Hand cars and trucks are a live source of danger to men unless properly used, and pony cars are a menace to traffic unless correct rules are observed. Men have lost their lives by being thrown to the ground when a hand car has jumped

the track because of having been run too fast, or through the breaking of an axle. A rule should be made that hand cars must never be run at a greater rate than 10 miles per hour. Men are also injured while sitting on the platform of a car, by being caught by the descending handles, while a man alighting in front of a moving car and tripping may very likely be run over with serious results. The breaking of a handle while the car is being propelled will frequently entail injury or death. It should be the foreman's duty to see to it that his hand car is always in fit condition. Many of these dangers are overcome by the increasing use of motor cars.

The putting on and taking off of the hand car and truck are a source of injury to the men because it is a common practice for some of them to move backwards in performing this act. It is just as easy always to walk forward, and the men can then see where they are walking. Neither the hand car nor hand truck should ever be overloaded, and care should be taken to keep the bearings well lubricated. Unauthorized persons should not be permitted to travel on the car and, to prevent boys or mischievous persons doing so, it should be kept locked when not in use. The use of the hand car or truck is generally prohibited in automatic signal territory and when this is permitted the cars are insulated so the

Pony Car Moved Properly

signals are not operated by them. The need of a car at such places may sometimes be adequately met by the use of pony cars.

The pony car should only be used on the outside rail of the outer track and should generally be moved against the current of traffic, although for short distances this rule may be suspended. While it is generally unnecessary to supply flag protection for the pony car, there are situations where it should be done, and it is always best to be on the safe side. Men should not ride upon these cars in sport; the presence of the car upon the rail should always be justified. In congested districts it has become the practice to operate motor trucks for the delivery of supplies and the smaller items of material. These run upon the city streets and reach the railroad at convenient intersections. While this service is not economical, it must be resorted to where the hand truck or pony truck cannot safely be used.

36. The Tool Grinder

The tool grinder with its several attachments is a modern device for reducing maintenance costs by facilitating the work of sharpening edge tools, such as track drills, adzes, chisels, axes, scythes, etc. By its use nine-tenths of the time required to do the work with a grind stone is saved, and a truer edge obtained. Since sharp tools mean more and better work the advantages of the grinder are unquestionable. The tool is portable and may be affixed to the tool house bench or to a section car. It may indeed be connected with the power of the car and thus the greatest possible speed of the tool be obtained with a minimum of labor expended.

The grinder operated electrically or by compressed air is useful in maintenance for grinding off the burrs along the outside of stock rails which might cause interference with the working of the detector bars. It has been employed frequently in making the pocket in stock rails to house the points of switches. It is forbidden to do this work by chipping the rail with a cutter on account of weakening the structure of the rail and thus inviting fracture. The electric grinder has been used in several instances to plane out the throat of frogs, switches and mates in girder rail work, where wheel

clearances are insufficient. The grinder is occasionally of use to dress off a spur left at the end of a rail in cutting it with a chisel. The point to be observed in the use of the grinder is that the speed be made as high as possible, and the tool to be ground be lightly but evenly pressed against the wheel.

PART II TRACK

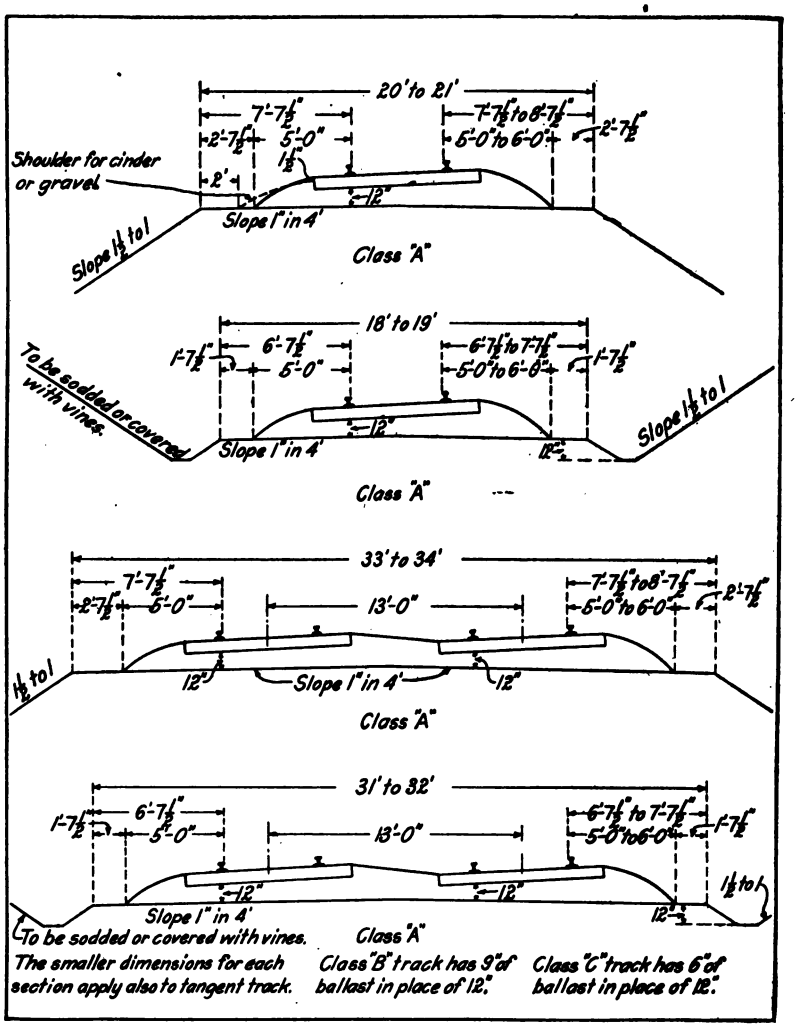
CHAPTER VIII

THE ESSENTIAL ELEMENTS IN MAINTENANCE OF TRACK

37. Drainage, Cross-tie Renewal, Line and Surface

The Principal Elements—There are certain basic requirements for substantial track which may not be slighted. They are, generally speaking, three in number: Good drainage, of which the principal adjuncts from the track standpoint are roadway design and ballast cleaning; adequate crosstie replacement; and proper force and method for maintaining the line and surface. There are other important items, such as: Organization of the repair forces; renewals of rail; and the use of track accessories; but those first named are of primary consideration. While the drainage of the track is interlaced with that of the roadbed, which was discussed in the preceding division, the point cannot be over-emphasized that effective drainage both of the track and roadway, is the prime essential in the upkeep of the railroad. This condition is obtained for the track through the medium of a well designed subgrade and of a clean and properly compacted ballast bed.

Standard Sections of Roadway.—The subgrade is given a pitch of about 1 in. in 4 ft. which, in the absence of pockets suffices to drain the water quickly to the sides. A further advantage is obtained by the establishment of the two inner tracks of a four-track system 3 in. higher than the outer ones. This arrangement incidentally effects a saving in the cost of the tie renewals of the inner tracks. Standard sections of roadway have been shown for the several classes of track, on tangents and curves, in cuts and on fills, and for the different kinds of ballast. Although these sections are of a wide application, experience will suggest modifications which may be desirable for particular localities justifying a more elaborate section, or may be necessary where as high a standard in maintenance is not permissible.



Standard Sections of Roadway

For class A track on heavy traffic railways an 18-in. bed of ballast is provided, which is underlaid with a 12-in. bed of ash-pan cinders. However, many double-track lines are efficiently maintained under a heavy traffic load with a 12-in. bed of ballast beneath the ties. For Class B track on such lines, a depth of 9 in. is sufficient, and for Class C track, a depth of 6 in. The side ditches in cuts on the main line of the Pennsylvania are 3 ft. below the rail, but for roads of average maintenance a depth of 12 in. below the sub-grade in all classes of track is considered adequate. This depth of course is increased when the grade of the road is not sufficient to afford free passage for the water in the ditches. In all cases the ditches are turned outward at their ends so that the rush of the water will not scour or erode the embankment.

Clean Ditches Essential.—The ditches need to be kept clean, not only to perform the important function of draining the roadway, but also and mainly to afford the means of diverting the water from the track quickly. For this reason it is forbidden to let the dirt cleaned from the ditches remain at the end of the ties where it will dam the water flowing out of the track. Similarly, when embankments are being widened the material should be leveled at once to a proper distance below the tie. Neither a perfectly designed roadbed nor clean ditches are effective unless the ballast is kept clean, and this is one of the principal objects kept in view in all track repairs.

38. Ballast Cleaning

Depth of Cleaning.—The periodical cleaning of stone ballast in the track is considered of such importance that many roads have definite rules governing both the manner of doing the work and the depth to which the cleaning should be carried. The universal method of cleaning the ballast is by means of forks, with the use of screens effective in certain cases. The depth to which the cleaning should be carried is a variable one, but it should generally be to the bottom of the tie in the inter-tie spaces and several inches below the bottom of the tie in the ditches. The cleaning of the ditches somewhat below the bottom of the tie is further desirable as a labor saving item, because when the sub-grade is reached work with the

ballast forks is greatly facilitated. Blind cross drains, for leading the water from the center ditches to the side, are necessary at frequent intervals, and they require cleaning to the same depth as the center ditches. The cleaning of the shoulders should extend to the subgrade, which is generally about 18 in. below the bottom of the ties.

Raise Out of Face.—The cleaning of track is not of maximum benefit until a raise is made and a clean bed of ballast applied beneath the ties. If there is a good sub-bed the raising may be done in lieu of the cleaning of the tie spaces; or, similarly, if the tie spaces are cleaned the raising may be omitted; although track never suffers from a light surface raise. Indeed, periodical raising, particularly on lines of heavy tonnage, is the life of a main track. The raise should generally be about 2 in., which can be made without flagging.

Frequency of Raising.—The periods between successive raises are variable for different kinds of roadbed and for different classes of traffic. Generally, for a well-maintained track, mostly under passenger traffic, raising once in four years is sufficient; while under a traffic with heavy freight movement predominating, once in two years is none too much; and there are places where the service is extreme and the roadbed bad that require this treatment every year.

Center-bound Track.—Its necessity is determined by the appearance of a center-bound condition of the track which fails to give comfortable riding even when the line and surface are perfect to all appearances. The condition, as is well known, arises from the track having settled into the bed until the unyielding part of the tie support is at the middle of the tie. It is to postpone this condition that maintenance rules prescribe that the tamping shall not be carried more than 15 in. inside the rail.

Raising After Tie Renewals.—When the roadbed is very hard, raising of the track in advance of the tie respacing or tie renewal effects some saving in labor. Generally, however, when the tie renewals amount to at least six in a rail length, it will be found economical in the long run to renew the ties first and then follow with a light surface raise. In the absence of such raising the new ties will require tamping at

least three times before they are solid, and this necessitates cleaning out two-thirds of the spaces for the tamping. The labor of tamping the other two-thirds of the ties a single time is no more than the labor of twice digging out and tamping the one third that were renewed. By the raising a uniform bed is obtained for all the ties, and the advantage in ballast cleaning fully offsets the additional cost for ballast.

39. Crosstie Replacement.

Features Rendering Ties Unserviceable.—There has been at times in the past great activity on the part of maintenance officers to effect a stringent restriction in the use of cross-ties. The thought doubtless was that such a restriction is a maintenance economy, but it is a temporary saving, the direct result of which will be measurable increase in the labor of maintenance later on. There is a stage in the life of a cross-tie when no matter what its apppearance may be its usefulness in main track is ended. When continued respiking through the absence of tie plates has resulted in the condition best described by the expression, "spiked to death;" when through repeated tamping the bottom of the tie has become rounded and has no base or an insufficient one for adequate bearing upon the bed; when through decay the function of preserving the gage or the surface is lost; then the continuation of the tie in a main track becomes a separate item of expense. Every main-line supervisor knows that the track which has a large percentage of inferior ties is the one where most of the sub-division labor is spent.

Importance of Complete Renewals.—Appreciating the importance of good tie support the supervisor should carefully ascertain the normal renewals for his sub-division, and it should be zealously sought to apply the indicated number of ties year by year. The total number of ties in the main tracks of the main line, divided by 7, in the branch main tracks, divided by 8, and in the sidings divided by 9, will supply the average yearly requirement, where untreated ties largely predominate or where past use of tie plates has not been plentiful. It is assumed that the mileage will be corrected for new tracks that require no renewals and for the stretches through switch connections and over bridges. These

figures are only approximate and apply on roads where a moderately heavy and fast traffic is carried, and where average climatic conditions are present.

The necessity is well recognized of a proper selection of the kind of timber for various situations, and of definite rules for inspecting, installing and protecting the ties, and this subject is covered fully by the maintenance rules of most roads. The practice of the Pennsylvania, which is fairly typical, is discussed further on under an appropriate heading. The essential point to be noted in this connection is that the continuing excellence of the track demands that the required number of ties shall be used year after year. The maintenance of good timber on bridges and through switch connections is equally important.

40. Line and Surface.

Program for Line and Surface.—The maintenance of a good railroad basically requires that the drainage shall be well taken care of and that the ties shall be kept in a sound condition; but there is also necessary the periodical repair of the track as regards the line and surface. This repair should be made on a regular program to be of the maximum benefit. Immediately upon the passing of winter a general lining and surfacing of the track is always first in order, to restore the road to as good riding condition as possible. A period is then entered upon of steady prosecutions of tie renewals, ballast cleaning, rail replacement and track raising. The main track tie renewals, which on all roads is the most important item in the repairs, will ordinarily be one half completed by the middle of June, and entirely completed by the middle of August. These two dates, in the majority of cases, prove favorable times for suspending the renewals during a brief period, in order that detailed attention may be given the line and surface.

Policing Along With the Renewals.—As far as possible during the period of applying material the road will be cleaned of scrap, old rails, old ties and dirt. Since it is not practicable on busy lines to keep the work train cleaning nearly even with the progress of repairs, these intervals, while active renewals are suspended, will supply the time needed for com-

pletion of the cleaning; and thus at definite times during the season the road will be fully policed. It will be noted that the dates indicated for the restoration of ideal conditions closely approximate those of the two national holidays, In-

Surfacing on Main Line

dependence Day and Labor Day, occasions when travel is usually the heaviest and a good appearance specially desirable.

Organization.—Since floating gangs are proverbially inefficient in the finer surfacing their labor should be mainly devoted to rail renewals and ballast cleaning. With such work lifted from the sub-division forces it has been found that efficient results in maintenance are secured by an allotment of laborers in a direct proportion to the number of miles of main track, provided that those subdivisions which have interlock-

ings or other special burdens are alloted additional force. The detailed subjects of lining and surfacing are treated more fully in a succeeding chapter, in which rules are stated for their economical performance.

CHAPTER IX

A PROGRAM FOR M. W. & S. WORK.

41. Practice on a Main-Line Subdivision.

Importance of Systematic Work.—The importance of system, as well as method, in track work has been recognized on many roads for a number of years. The engineer maintenance of way of one of the largest trunk lines ascribed the improvement made in one year on his road to the particular attention devoted to systematic work on sections. Several recent discussions have emphasized the advantage of standardizing maintenance-of-way work, and of placing the organization upon a permanent basis throughout the year.

Program on a Main-Line Subdivision.—A detailed program, which was followed closely in the upkeep of a main-line subdivision in the eastern region, is given as of more than passing interest to maintenance men in general and of special concern to those charged with maintaining high speed lines under exacting conditions. The various percentages in the several items of work were adopted by the supervisor after a careful study of the repairs through several typical years. Care was taken to develop a schedule with alternating periods of intensive repair and entire suspension of renewals. Excluding the four months comprising the closed season, the remaining time was divided into four periods of two months each and the dates generally defining these periods were established as points of peak excellence in the maintenance of line and surface.

Instrumental Tests.—Throughout the year the practice was rigidly followed of proceeding each established date with a period of general lining and surfacing. During this period tests were made frequently, using a water spiller and track instrument. The spills and vibrations were recorded for each foreman's section and the exact time of passage noted in minutes and seconds. Readings were also taken for certain

PROGRAM FOR M. W. & S. WORK

Month	Percentage of ties to be renewed in main tracks at end of month.	Progress.	Percentage of ballasting to be completed at end of month.	Progress.	Percentage of rail renewals to be completed at end of month.	Progress.	WORK TO BE ENGAGED IN
Jan. ..					15		Laying new rail, constructing standard ditches, removing snow and ice, surfacing, shimming and gaging.
Feb. .					30		Laying new rail, constructing standard ditches, removing snow and ice.
Mar. ..					45		Mainly surfacing, continuing rail renewals, starting tie renewals, policing the road, installing under drainage.
April .	27		25		50		First half—laying rail, putting in ties, raising track where tie renewals were made; Second half—surfacing track.
May .	46		35		65		Vigorous prosecution of tie renewals, rail renewals and track raising, with as ample policing as possible.
June .	57		50		70		First three weeks—continuing rail and tie renewals; last week—surfacing, including track raising; mow the right-of-way middle of the month.
July .	72		68		85		Continuing rail and tie renewals.
Aug. .	90		78		90		Vigorous prosecution of tie renewals; track raising, rail repairs, with as ample policing as possible. Second half—lining, surfacing and gaging.
Sept. .	95		90		95		First week—surfacing and lining; remainder—general policing of roadway ballast border and ditches, with rail and tie renewals in sidings. Mow the right of way the first week of this month.
Oct. ..	100		100		100		Final policing of the road, along with necessary lining, surfacing and gaging and repairing of road crossings.
Nov. .							Surfacing and lining in order to enter upon the closed period in the best shape possible.
Dec. .							Cleaning snow and ice; keeping ditches open; making standard ditches where possible.

SATURDAY, between June and September, to be devoted to policing, cleaning up scrap, pulling grass and weeds. One-third of the time of the track-walkers also to be used in policing.

TWO DAYS EACH MONTH to be devoted to tightening bolts.

LAST WORKING DAY EACH MONTH, bridge seats to be cleaned thoroughly.

When making tie renewals, three and a half days to be devoted to putting in ties, one and a half days to surfacing or raising of the stretch renewed.

portions of the sections when thought desirable, and the deficiencies indicated by the record were communicated to the foreman concerned. A resultant was calculated for each section and from these a rank was given, the complete figures being made known to all foreman. When there were any special features that operated to handicap the section, a proper notation was made. These tests inspired considerable rivalry, especially as the final standing determined the supervisor's recommendation for the awarding of the several foreman's prizes at the close of the working season.

Seasonable Track Work.—The program of work takes fully into account the advantage of seasonable distribution of track work. It provides especially for the making in winter of such renewals as may practically be done in the closed season, to the end that forces may be kept uniform throughout the year. By extending the more active renewal of ties over six months of the year assurance is obtained that good riding will not be sacrificed to a too rapid progress in repairs. The occasional suspension of tie renewals for short periods enables the excellence of the line and surface to be maintained, the road to be cleaned of accumulated dirt and old ties and the material to be distributed systematically which is required for use in the succeeding period.

Noting Progress in Repairs.—It should be fully understood that the program is not merely an ideal scheme to be vaguely followed, but a schedule to be met substantially month by month. As will be noted, a blank column is provided in which to enter the progress made in the three special items. The percentages of completed work are computed from the material reports and entered upon the program at the end of each period. The supervisor is able to keep constantly informed of the progress being made through the daily material and time reports. Observations should be made to detect lack of compliance with the program in policing, tightening of bolts, cleaning of bridge seats, and in the manner of making tie renewals. While the suggested program employs but three items for detailed recording, these being such as are of universal application, it might happen that the ditching program planned for the year would be of such definite scope as to form an additional item; and still other items might be added.

The Tie Program.—A sound condition of the ties is recognized as an essential element in the maintenance of a main running track. Lacking an ample repair in this particular, no track is adequate for the severe operating requirements of today. It thus becomes of the highest consequence steadily and persistently to prosecute the renewals until the required number have been applied. The estimated quantities are arrived at by different methods on various roads. When they are not wholly reliable through having been taken too long previously, or for any other cause, recourse may be had to an empirical rule. Records have been kept to such good purpose that upon any well maintained road the requirements for a certain class of track can be approximated by a simple calculation. These records determine the life of the tie in main track, and while the figures may vary considerably through diverse climatic conditions and unequal traffic burden, and present extensive use of treated ties and tie plates will cause the figures to increase progressively, a sufficiently accurate basis is supplied for checking the progress of repairs.

The Ballast Program.—The ballast program is in the main reciprocal with the tie program, for in surfacing the road light lifts are made which consume the ballast chargeable to expenses, the larger reballasting operations having no part in the repair program. The main advantage in thus regulating the flow of ballast is that the tie renewals are followed closely so that the fine line and surface do not deteriorate through insufficient back filling. This sequence tends also toward the preservation of a neat appearance during the period of repairs. A definite progress in ballasting is important because when back filling is deferred until fall, the material may not be obtainable and the tracks thus remain empty through the winter, a condition which strongly contributes to trouble from heaving.

The Rail Program.—In the item of rail renewal there is a possibility of divergence through the material not being supplied promptly; but it is believed the program can be substantially complied with under normal conditions. It will be noted that a large percentage of the rail is scheduled to be applied in the winter and early spring. This is rendered practicable by the increasing use of plain base splices and the

ability to postpone for a time, or to omit altogether if desired, the respacing of the ties. The program co-ordinates the laying of rail to some extent with the several surfacing periods, because the latter work necessarily requires attention from the section forces, and there would otherwise be interference between the two items of work.

Use of Program in Minor Items.—The advantage of having a definite program for the lesser items of maintenance work is quite tangible. It is vastly easier to regulate the conduct of the subdivision if all the section forces are engaged in substantially the same kind of work. The matter of mowing the right of way is important enough to have a specific date set for the two mowings. By having this work completed at one time there is realized the full benefit from the improved appearance. The indicated plan for policing the road has been found to give excellent results. It is well known that unless

Well Policed Stretch of Road

a regular time is designated for doing this important work it is liable to be left undone.

The tightening of the bolts is a similar item which is apt to be neglected unless a set time is regularly employed. The benefit derived from attention to this item is shown not alone by an increased safety of the joints and greater freedom from noise, but by improved riding of the track. Instrumental tests have shown conclusively that the vibrations are more numerous over track containing a large percentage of loose bolts. The specific advantages of the program of work are:— That it standardizes repairs; supplies a compact exhibit of the progress of renewals; fixes a basis for supplying the material; and tends to provide a definite assurance that the season's work is being done.

CHAPTER X

THE TRACK OBSTRUCTION.

42. Limitations in Maintenance Operations.

Definition of Track Obstruction.—Elaborating the rule somewhat, a track obstruction, in so far as it relates to maintenance work, may be defined as any condition which will not permit the passage of a train at full speed **with an ample margin of safety.** The provision emphasized has become specially important by reason of the higher standards being established for railway operation. It is a well known fact that in the past conditions have sometimes been found to exist, which would be pronounced inadequate if gaged by the standard of a definite factor of safety. It is not enough that trains "get over alright;" they must be passed with such absolute assurance of safety that no single element of doubt is present. Whenever the safety of a situation admits of argument, a flag should be sent at once against trains.

Need for Limitations in Track Work.—To meet the changing conditions in track construction it is essential that limits be determined for the various processes. The problem of applying the heavier sections of new rail is alone a most serious question. The declining quality of the laboring forces, the frequency with which they change from place to place, the loss of the native and experienced labor formerly counted upon, have made a new situation which must be met. Although the exact conditions that require protection will vary somewhat with the standards and the degree of maintenance of the road, it is thought that rules designed for use on a trunk line of high ideals in maintenance will supply helpful suggestion in such determination.

Means of Protecting Traffic.—A prime requisite for the efficient protection of traffic is a rigid requirement that the track forces shall have close at hand the proper appliances for conveying stop signals quickly in the event that a sudden emergen-

cy should require it. Whenever such a circumstance arises men with red flags or red lamps should be sent in each direction a sufficient distance to stop a train before it reaches the point of obstruction. They should also be provided with torpedoes to be used in the manner prescribed by the rules. At the immediate place of danger a red flag or lamp should be placed within constant sight of the men on the ground. In automatic signal territory a shunt rod should be used to set the nearest signal in the stop position. Prompt information should be given the despatcher so that notice of the obstruction can be handed the train at the block stations.

Reliable Flagmen Necessary.—It is the first duty of every foreman to select with the utmost care and train with thoroughness men upon whom full reliance can be placed to supply unfailing protection. The instructions he gives them must be positive to flag every train until called in. The practice of allowing the flagman to pass certain trains while protecting is wrong and should never be permitted. While some loss of time may be suffered if he is called in and again sent out, the matter of safety far outweighs every other consideration. It is essential that the flagman shall be able to speak English intelligently, as it is necessary that he be able to inform the engineman why he is being flagged. This information conveyed in broken English might lead to misunderstanding and consequent accident.,

Limitations in Relaying Rail.—The specific conditions which have been determined by careful study to exceed the limits of permissible departure from the ideal are given categorically. It is believed that adherence to these standards will always conserve safety without unnecessarily restricting maintenance operations. In the relaying of rail the following features are considered to introduce an obstruction to safe movement: A greater number of spikes withdrawn from a single line of rail than at every other tie; less than one bolt in either half of any joint or these not tightened; a poorly applied connection joint, introducing an offset in the gage line or a step from the higher to the lower rail; the loosening of more than half the spikes along the inside line of the rail through any part of the stretch to be relaid.

Collateral Requirements.—It is further required that the ties

at the point of renewal shall be in the sound condition that should at all times be present in main line tracks. If the ties are not sufficiently sound, proper replacement should be made before the relaying of the rail is undertaken. The drawing of spikes has been limited to a single line of rail because there is the possibility that the alternate spikes might be withdrawn from a different series of ties for the two rails and thus no protection against spreading of the rails be afforded. Accidents have occurred through such a condition being overlooked in the hurry of renewal. It is required that two bolts be in place, one in each half of the joint, to insure that the rail will not pull apart while a train is passing over it. Wherever possible the difference in height of the two rails or the offset in the gage at a compromise joint, should be no more than ⅛ in. The raising of the spikes is necessary where a rail section with a heavier base is being applied. While this lifting may be done in advance upon the outside line of the rail, it may not be done upon the inside line until the last train has passed. The laying of rail is of such importance that this work on the main line should if possible be always directly in the charge of an assistant supervisor; thus an officer of the company will assume responsibility for the safety of the operation. This is especially necessary on those roads which have made radical changes in the standard rail section, as from a height of 5-½ in. to 6-½ in., and from a width of base of 5 in. to 5-½ in., both combined with a radical increase in the width of head. The problem of the gage, as well as of compromising the several sections, requires the presence of someone having mathematical attainments.

Limitations in Renewing Ties.—A condition that is unsafe may be introduced by an improper manner of making tie renewals. The removal of two or more ties together, or the removal of more than 4 ties in any 33 ft. section of track, or lack of full spiking or tamping at the ties adjacent to those removed, constitutes an obstruction requiring protection. The weight of the rail in the track is the principal element in determining the permissible space between the bearing surfaces. With 100-lb. rail, where maintenance is good, it is believed no obstruction will exist when the span is not greater than 27 in., or, for very short periods while one tie is removed in renewal,

when the span is no greater than 48 in. Such a condition should not extend beyond a few train movements and should never be allowed to run over night. It is preferable that the spaces should be maintained as far as possible within 18 in. The limiting maximum spans should be reduced for weights of rail less than 100 lb. in the ratio of the squares of the respective weights to the square of 100; and they may similarly be increased for heavier weights.

Limitation in Raising Track.—In raising track under high-speed operation lifts greater than 2 in., requiring a measurable time to apply a run-off at least as moderate as 5/8 in. in 33 ft., or a change of elevation greater than 1/2 in. in 33 ft., or in any service, the use of the track jack within the rails, would constitute an obstruction. Tests with the newer and stiffer equipment have shown that the side bearings will foul at the diagonally opposite corners when the rate of the run-off is greater than 1-1/2 in. in 33 ft. In any maintenance a margin of practical working variation must be assumed, and it seems fair to propose 1/2 in. as the limit to which irregularity of elevation might go. If this limit is adopted the run-off for moderate speed may be established at a rate of 1 in. to 33 ft.; but where 3/4 in. low joints might occur a rate of 3/4 in. to 33 ft. should not be exceeded. A rate of run-off in excess of 1/2 in. in 33 ft. should not be used where a speed above 45 miles per hour is permitted. These restrictions apply whether the change in elevation is the approach to a curve, a neglected depression in the grade, or the run-off when a single rail is being raised. To avoid the latter menace it is customary to raise both rails together, and, for greater comfort to the passenger, the raising is made toward the traffic.

Limitations in Gaging Track.—An obstruction in gaging track exists when the spikes are removed from more than every other tie on one side of the rail, and removed or lifted from more than four adjacent ties on the other side of the rail at the same time. If in spike-lining the gage should be tightened to less than 4 ft. 8-1/8 in. or widened to more than 4 ft. 9-1/4 in., an unsafe condition would be introduced which would require flagging of the track. From the fact that gaging must generally be done by laborers working in twos and threes, without the supervision of the foreman, this rule is important

and should be carefully impressed upon those to whom this responsibility is entrusted. The condition stated may develop from rail running or track spreading out, and the rule should likewise be impressed upon the track walker.

Limitations in Lining Track.—A track obstruction exists when both splice bars at a joint are broken entirely through, and similarly, when renewal is made of both splices at the same moment. This work should always be delegated to two men so that one can supply necessary protection. Any operation in lining in which the throwing exceeds that usually done in ordinary maintenance is an obstruction. It is not necessary except in special cases to do the lining in a manner to cause an obstruction. It should always be done gradually so as not to introduce any menace to the traffic.

Efficiency Tests.— The matter of working to the exact standards set for the various processes is of such consequence that several roads now require efficiency tests to be made regularly to insure compliance with the rules. These tests are made by the supervisor and also by the members of the safety committee. The results of the tests are recorded and violation of the rules is adequately punished. Tests are made by the division engineer when rail-laying is in progress to determine that the supervisor or assistant supervisor is in charge of the work. The renewing of ties is strictly the work of the foreman and this item is especially observed. The tests are made by surprise and the aim should be to try each foreman at least once a month. The other items of work, such as gaging, changing splices, raising track and lining, are occasional, and the tests will be made as opportunity presents.

CHAPTER XI

LABOR SAVING DEVICES AND METHODS IN TRACK WORK.

43. Statement of the More Common Items.

Avoiding the Need of Respacing New Rail.—The discussion of this subject very properly includes consideration of the means for increasing the life of track materials when a saving in labor is directly effected thereby. One of the livest questions in track practice is whether the joints should be spaced after new rail is applied. The general conclusion seems to be that for the finest results spacing should ultimately be done, but that for medium or economical maintenance it may be omitted. On one important trunk line of high-class standards a method is in use which minimizes the spacing necessary. In relaying rail on tangents a special length 4 in. shorter than the standard is applied as soon as the rails have advanced one-half that amount, and a length 6 in. shorter similarly is used in relaying on curves. This practice is open to the objection that odd lengths of rail are introduced at isolated points; but this may be met by emergency store at suitable intervals. The method effects a considerable saving in labor and the advantage of slot anchoring the rails is thereby retained.

Saving Effected by Square-end Rails.—In relaying rails as ordinarily practised, and invariably in applying switch connections, special lengths of rail are necessary. The ordinary method is to score the rail and break it by a fall. Rail saws not only provide a more accurate measure and a smoother joint, but of greater importance, they furnish a perfectly square end. The disadvantage of even slightly skewed ends is not fully appreciated. When the joint closes up in warm weather there is the certainty that the unsymmetrical bearing will cause the rail joint to push out or in. In either case the finer line is disturbed and indifferent riding of the track re-

sults. The same condition is brought about when faulty inspection permits the acceptance of rails that are not square on the ends when shipped from the mills. It would pay the better maintained roads to have all the new rail re-inspected after delivery upon the ground and the rails which are not square culled out to be used in some other place. These rails might be resawed to furnish the 4-in. or 6-in. shorter rails mentioned previously. This matter is of special importance in the case of the heavier sections.

Curving Rails.—A decided saving in maintenance of the sharper curves is effected by curving the rails before they are put in the tracks. This is desirable for curves above 4 deg. and must always be done when the curvature exceeds 18 deg. Tables of ordinates for curving rails have been computed, but they are of little use in the operation of bending the rails. It is well known that a variable amount of curvature is lost when the rail bender is released, and it is therefore necessary to find by trial how much curve to introduce to net the final figure desired. A convenient rule for determining the attainment of the desired curvature is to use for the middle ordinate of a chord 7 ft. 9 in. in length as many 64ths of an inch as the degree of curve sought. It is well also to remember that middle ordinates for equal curvatures vary nearly as the squares of the chords. In performing work with the bender it is important that the tool be properly applied to avoid possible injury to the men from its becoming dislodged while a strain is being applied. The best results are obtained when the rail bender engages both the head and base of the rail.

The Rail Layer.—In relaying rail, especially on branch lines, one of the principal difficulties is to assemble a sufficient number of men to set the rails in place. A small hand-operated rail layer, consisting of a carriage and boom, which travels on the opposite rail to that being installed, and on a temporary light rail set just inside the final position of the latter, is much used for this purpose. The rail is lifted by means of winches and moved inward on the carriage to its proper position, and then let down on the ties. The rails may be set in place at a speed equal to that of a large gang using tongs. While it probably effects no large saving in expense, it allows the work of relaying to proceed with

only an ordinary section force engaged, and thus conserves man power. The device is also a means of overcoming the known antipathy of present labor to the heavy exertion of carrying rails.

Cleaning Ballast with Screens.—Cleaning the ditches by forks is a slow and expensive operation and several methods are in use for saving the excess labor required in hand processes. The utility of screens in cleaning stone ballast is recognized, and several roads require that ballast be thus cleaned wherever practicable. The dirty ballast is loosened with picks and thrown upon the screens inclined at an angle of 30 deg. with the vertical. The screens are designed to be dropped instantly below the level of car bodies and with proper attention involve practically no element of danger. The dirt is caught in bags and carried to the side to be wasted or loaded upon the work train to be used elsewhere. Power ballast screens are in use which through a belt conveyor deposit the dirt at once to the side of the roadbed. It has been found that this dirt with the coarser stone later raked out of it makes an excellent covering for the shoulder on fills. Its black color contrasts pleasingly with the lighter stone, and it is the best material known for retarding the growth of weeds. The particular labor-saving feature of screens is that the dirt is collected at once into receptacles, and thus one handling is avoided. It is also probable that some labor is saved in the forking of the stone.

Special Method of Cleaning.—It would be impracticable to clean the ballast over an entire subdivision every year, nor is this necessary. A year after cleaning it will be found that the dirt in the ballast extends to no greater depth than 2 or 3 in. A method is in use by which the dirt is let down to a depth below the bottom of the tie with a minimum of labor. A rift is made across the center ditch to a depth of 2 in. below the bottom of the tie. With this beginning, the clean ballast beneath is then drawn to the surface, the dirt by the process going to the bottom. It is done entirely with the picks, by a motion somewhat similar to kneading. It may be done a second or even a third year, after which time a general cleaning is necessary. Each operation not only improves the appearance of the roadbed, but gives better

drainage, and does not cause the intertrack spaces to become mounded as occurs in the method popularly known as "galvanizing." A man can clean 150 ft. of center ditch in this manner in one day.

Economy from Oiling Track Bolts.—The practice is becoming more common of oiling track bolts to facilitate their tightening in service or their removal when rail renewal is projected. The importance of tight bolts, not only as a protection for the joints but as a factor in the riding of the track, is fairly well appreciated. Much labor is lost in trying to tighten bolts that are corroded. An occasional application of oil by the trackwalker costs nothing additional for labor and little for the oil and reduces by fully one-fourth the labor of tightening the bolts. It will likewise save many bolts that would otherwise have to be replaced. When the old rail is being uncoupled after renewal, practically all the bolts may be removed and used again if oiling has been done periodically.

Pneumatic Drill and Hydraulic Bender.—In switch work and to some extent in relaying rail, it is necessary to drill a number of bolt holes. Any considerable job of this character should be done with pneumatic or electric drills whenever access is afforded to a compressed air line or an electric main, or where a portable compressor or generator plant is part of the tool equipment. A test with the mechanical method in comparison with hand drilling has shown that the former method is four times more effective than the hand method. The hydraulic rail bender is useful for breaking the closing rails in relaying when the break must be sure. It is not only quicker than most other methods, but it can invariably be relied on. It is also useful for introducing the bend required in the stock rails at switches, and is unequaled for bending the rails for the sharper turnouts. With this tool the labor of one man is equivalent to that of four with the ordinary type of bender.

Rapid Track Wrenches.—A quicker means of applying the nuts is needed than the present slow one with the standard track wrench. None that is practical enough for use in service tracks has yet been designed. Ratchet wrenches screw the

nuts up, but they must be tightened with the long wrench. There is in use a special wrench 8 in. long with one end tapered to the section of the bolt, which answers the purpose of applying the bolts quickly in relaying rail or changing splices; but it must be followed with the track wrench to obtain full tension.

Special Lengths of Rail for Road Crossings.—In the use of long rails through road crossings to eliminate joints it is the usual practice to apply 60-ft. rails. While this is satisfactory where these rails are introduced along with the laying of new rail, it is not of practical use where standard 33-ft. rails are to be removed only for that object. Many roads now specify 26 ft. for one of the shorter lengths accepted with a rail order. A 40-ft. special length in combination with a 26-ft. length, used on one or both lines of rail, will nearly always remove the joints from the crossing, and preserve a sufficiently long staggering of the joints, about 9 ft. 6 in., to conserve the line. The saving in maintenance by this practice is considerable. It is well known that joints in crossings require fully twice the surfacing necessary at ordinary points, and the labor of tearing up the crossing is an added expense. The presence of joints is also a contributing factor in the heaving experienced at crossings in freezing weather.

Use of Hardwood Ties in Crossings.—Much labor may be saved in the surfacing of track through road crossing by using only hardwood ties for such points and by maintaining the ties in the best possible condition. Renewals in face at road crossings are permitted not alone by reason of the expense of the renewing, but because good support is essential. The use of soft wood ties even with tie plates soon results in the tie being cut into and this causes canting of the rail. To prevent this tie plates are required even on hardwood ties.

Drainage at Crossings.—The maintenance of a clean bed of stone through road crossings is also desirable. The drainage at such points is apt to be inferior even when the best methods are used. The matter is of especial importance in automatic signal territory, as leakage of current may thus be reduced. Heaving in winter also is greatly modified by

good drainage at road crossings. A test of this matter was made recently on a road of the highest requirements. The ties at nearly all the road crossings on the subdivision were renewed late in the fall, the ballast being thoroughly cleaned at the time. During the succeeding winter not one of these crossings gave any trouble from heaving, while those that were not so treated required the usual attention. It is a well-recognized fact that otherwise good maintenance is often spoiled by unfavorable line and surface at a road-crossing.

Economy from Correct Gages.—A great amount of unnecessary work is entailed by the varying measure of the track gage. It is required that different forces shall do work at the same points, and the same tool is not always used by the section gang itself. If the gage is not correct, one of the essentials of standard track will be lacking. Finer results would be obtained in maintenance if each supervisor possessed a device for testing the track gages used on his subdivision. A simple contrivance, easily made in a blacksmith shop, consists of a flat bar of steel 3 in. wide by ⅜ in. thick, 5 ft. 6 in. long. into which two lugs of nickel steel 9 in. long by 1⅜ in. deep are mortised exactly 4 ft. 8½ in. apart and further secured by two lag screws countersunk. It should be required that the gages be sent in at definite intervals to be tested, when those that are incorrect should be properly adjusted. Standard methods of using the gage in track work should also be insisted upon.

Pneumatic Tools for Tamping, Spiking, Adzing and Boring.—About ten years ago a committee of which the author was a member suggested that a promising field for the development of labor-saving devices was the use of compressed air for driving spikes and possibly for tamping track. The latter has been fully realized and machines are in fairly general use for this work. The mechanical tie tamper is particularly efficient for the surfacing necessary at water stations and through switch connections. The machines have overcome the difficulty of reaching to all parts of the base of the tie which is essential for obtaining an effective tamping. The boring and adzing of ties that are to be equipped with tie plates and screw-spikes, as well as the driving of the screw spikes, is now frequently done by the pneumatic

process. The practical driving of spikes with the pneumatic hammer has not advanced so far, but tests have shown that it is possible of future accomplishment. In one experiment two men drove 240 spikes into ties of different woods in one hour. A 24-lb. hammer with 8-in. stroke was used, the air pressure varying from 80 lb. to 100 lb. A recent test with the pneumatic hammer in comparison with hand driving did not favor the former. Two men with spiking hammers in two hours drove 680 spikes, while three men with the pneumatic hammer in the same time drove 435 spikes. It appeared that the duty of the pneumatic tool was capable of increase, and the work performed by the spikers was greatly in excess of ordinary experience.

Use of Locomotive Cranes.—Locomotive cranes have recently come into favor as labor-saving devices in track

Locomotive Crane Handling Track Material

work as well as in roadway repairs. The principal uses of these machines are: In erection work; in pile driving; as a drag line scraper; for lifting and placing heavy materials,

especially at a considerable height; and, when equipped with a steam shovel arm, for excavating. They may be used to good advantage in such work about the track as setting in rails in relaying; delivering bridge ties from the ground to their place on the structure; the lining and raising of track; the shifting endwise of entire switch connections; and the installation of slip switches, both in new work and renewals. In the lining of track it was found the machine accomplished the work of 50 men with the bars. A considerable fill was made by the use of a temporary track into which the material was dumped, the raising of the track being done with the locomotive crane.

CHAPTER XII

TRACK MATERIALS AND THEIR USE

44. Ties

Ties of First Importance.—The cross-tie, in which class switch ties also are included, is the nearly universal means employed on a railroad for supporting the rails and maintaining them in gage. They are of primary importance in the track structure, because their kind and condition determines both the safety and sufficiency of the track. The inspection, storing, handling and applying of ties are matters of concern to the trackman, by reason of the fact that this material forms one-sixth of the expense of maintenance of way. The constantly increasing shortage of the supply makes the study of proper methods in the use of the material an operating necessity. As special ties are still in the experimental stage, further reference will not be made to them.

Treated and Untreated Ties.—The woods from which cross-ties are made are of two general kinds, the needle-leaved and the broad-leaved. The former class consists mainly of the heart pines and cypresses, used without preservative treatment, and the sap pines which require treatment. The latter class consists of all other woods, some being suitable for use without treatment and others of much lower value when not treated. The parts of a stick of timber are the pith, which is the center of the tree; the heartwood, or successive rings of annual growth; and the sapwood, which is distinct from the heart and ordinarily contains more or less moisture. Not all ties contain either pith or sapwood, but in all of them the annular rings may be distinguished readily.

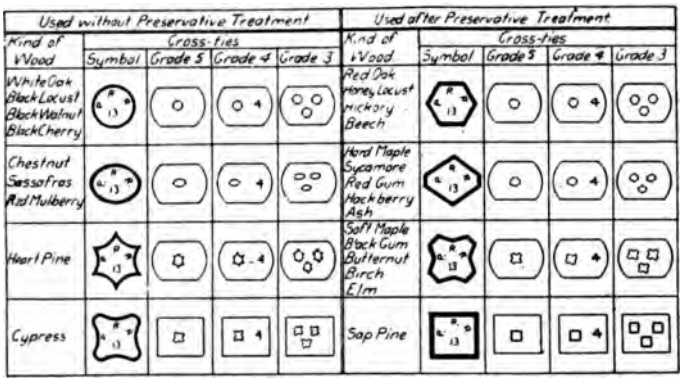
Common Methods of Treating.—The manner of preserving ties varies in different sections, being largely influenced by the climatic conditions under which the ties will be used. In every process care is taken that all of the sapwood is permeated and as much as possible of the heartwood. The

treatment preferred by the Pennsylvania is the straight creosote process by which the preservative is injected at a temperature of 180 deg. under a pressure of 150 lb. per sq. in., the quantity of creosote being 10 lb. per cu. ft. of timber. Treatment with zinc chloride in the quantity of 0.5 lb. per cu. ft. is quite common in the middle west, where the rainfall is moderate and where the ties used are principally from woods of the needle-leaved variety. The best results from this process are obtained by proper drying and seasoning of the timber before treatment. A combination of creosote oil in the quantity of 3.0 lb. per cu. ft. and zinc chloride 0.5 lb. per cu. ft. is not infrequently employed, especially for preserving red oak and hemlock ties.

Object and Effect of Treatment.—The essential object of the impregnation is to retard decay by excluding moisture and by exercising a toxic effect upon fungi and destroying insects. In general, untreated ties of the classes that require treatment will last 4½ yr., zinc treated ties 11 yr., and creosoted ties 16 yr., while ties treated by the combination process have a life about midway between the last two. It is assumed in all cases that the ties will be protected with tie plates. No treatment is of maximum use unless the ties shall have had at least six months' summer seasoning. The main object of the air seasoning is to expel moisture which would prevent full injection of the preservative; but all classes of ties are benefited by this seasoning since the chance of checking is lessened and greater strength and durability are obtained.

Symbols for Untreated and Treatment Ties.—Standard specifications now establish five grades of ties, which in detail are not unlike the older classification except that the order in common use, which embraced but four grades, was reversed, the No. 1 tie becoming No. 5, and so on. There are specific rules that apply to the different classes and grades of ties, and it is therefore necessary that the trackman shall be able to determine at a glance the one to which a particular tie belongs. The classification of ties on the Pennsylvania and other roads is made by stamping the ties when inspected, with a distinguishing symbol. The figure varies for different groups of woods; but in all cases a symbol composed of

curved lines denotes a tie that may be used without being treated, and of straight lines one that should be treated before use.



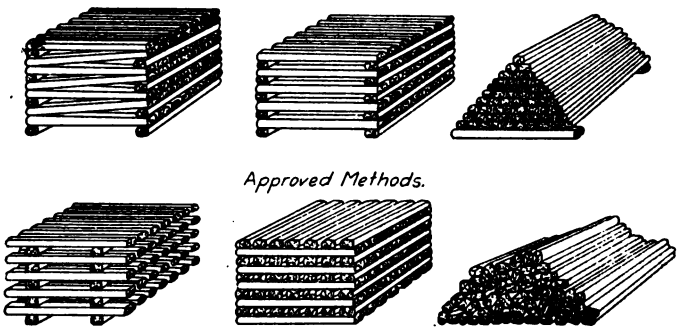
Methods of Marking Ties With Hammer Brands

Grades of Ties.—The brand also shows the grade of the tie, whether No. 1, 2, 3, 4 or 5, which must be indicated in order that the material may be properly charged in the accounts. The selection of the ties that are best adapted to service in the various kinds of track can be made readily upon a casual inspection by the foreman. While the rules specify the uses of the certain classes, they are not fixed and the foreman's judgment usually is allowed to govern. Thus, since inspectors are not infallible, a large No. 3 tie may be good enough for high-speed main track, while an inferior No. 5 tie may be only fit for siding.

Rail or Plate-Bearing Face.—A more important matter from the trackman's point of view is the means of deciding quickly which is the top of the tie. By the top of the tie is of course meant the side that should be placed uppermost in the track. That several laborers may not be held up in their work while this is being determined, it should be done beforehand as far as possible. The face selected for the rail or plate-bearing side will generally be the one that is farthest from the center of the tree; or, if the pith should be in the center of the tie, the narrower of the two faces.

There are several reasons for this selection. The essential purpose of the tie is to support the rail, which in turn carries the load. When the bearing width of the tie is equal to the width of the standard tie plate, the full efficiency as regards seating the rail is attained. There remains the item of bearing for the tie upon the roadbed, and the greater the width of bottom face, provided it is not more than can be fully tamped, the better will be the support for the track.

Placing the Tie with Heart Face Down.—Besides the structural elements in the selection, there is the equally important item of prolonging the life of the tie in the track. The chief forces tending to destroy the tie in use are splitting and decay. There is a much smaller probability of splitting the tie in the spiking when the spike is guided straight by the softer sapwood. There is also less likelihood of checking when the sapwood is uppermost. The decay of the wood is brought about mainly by the presence of water. The splitting furnishes a lodging place for moisture, and the upward concave structure of the wood when the heart is at the top tends further to hold the moisture within the wood. It has been made a definite rule, whether ties are being piled for storage or installed in the track, that the heart face must be down.



Proper and Improper Methods of Piling Ties

Piling and Handling Ties.—It is forbidden to pile ties in such manner that the rail or plate-bearing points shall be

in contact, and ties not intended to be used immediately should be kept off the ground. To avoid the danger of fire starting among stored ties, all material easily ignited should be removed for a space of 3 ft. around each pile. In the case of treated ties it is also necessary that the piles shall be plentifully sprinkled with earth. When handling any ties they should not be dragged with a pick, but the tie tongs or the hands be used invariably instead.

Ties Renewed by Spotting.—In renewing ties, those that are unfit for service should generally be removed by the method known as "spotting." This expression means that only those ties are renewed which are marked or spotted to come out. No tie should be marked for replacement which will last one year longer, no more than three ties together should be changed in one renewal and no more than one-half the ties under one rail may be removed during a season, unless for special cause. The same rules are to be observed in the renewal of switch ties.

Renewals Out of Face.—Renewals out of face are permitted through station platforms, road crossing and half-through solid floor bridges. (The term "out of face" means that all the units in a continuous stretch are included.) These exceptions are made because of the extra expense necessary in the renewals and because of the importance of specially good ties at such points. When serviceable ties are removed in these renewals, or by error in ordinary renewals, they should be saved for prompt application in side tracks.

Handling the Old and New Ties.—Ties in the track should not be disfigured when they are being tested, because the appearance of the road will be unnecessarily injured and the life of the ties shortened thereby. Those removed from the track should not be broken up, since it is necessary that the supervisor and others shall observe the condition of the ties just as they were when taken out. The tie plates and spikes must be removed from the old ties before they are burned or otherwise disposed of. When old ties are held for inspection, they should be neatly piled for the sake of appearance.

In making tie renewals picks should not be driven into the new ties, especially those that have been treated, but the

tie tongs should be used for drawing them into the track. When the ties are twisted the adze may be used to provide a smooth seat for the base of the rail. They should never be notched for this object, although the rules of some roads permit the dapping of a seat for the tie plate. The ties should not be knocked into place with a spike maul in respacing, but a large-faced hammer should be employed for the purpose. If the tie is not too hard on its bed the necessary adjustment can be effected with a bar. Certain patented devices are in use which have been designed with a view to doing this work mechanically in conjunction with a track jack.

Alining Ties in Track.—When ties are being put in they should be made square with the track and they should be kept so. When they become skewed in the track the spaces are unduly increased and the gage is somewhat tightened. If the gage becomes more than ¼ in. tight an unsafe condition is introduced. Even a tightness of ⅛ in. in the gage at any point causes wear which permanently destroys the smoothness of the running side of the rail. It is therefore important that the ties, when they have shifted out of place, shall be realigned promptly.

Permissible Variations in Spacing.—The space between the bearing surfaces of two adjoining ties should, as far as practicable, be maintained less than 18 in. in main running tracks. The track is not entirely safe when the distance exceeds 27 in., but for brief periods while a tie is removed in renewing, the space may be as much as 48 in., provided the rail is not less than 100 lb. to the yard. If the ties shift closer to each other than 11 in. the tamping is made difficult. The distance between the bearing surfaces at joints should be as little above 11 in. as practicable. The largest and best ties should be selected for use at the joints and, when one end of the tie is larger than the other, the larger end should be used for the support of the joint.

Lining the Ends.—Since cross-ties are bound to vary in length the rules fix the manner of lining the ends. On four-track and double-track roads the outside ends are lined parallel with the rail. In the case of single-track lines it is customary to designate which side shall be lined with

reference to the established course of the road. When the standard length of the tie is 8 ft. 6 in., the distance from the web of the rail to the line end of the tie is 21 in. and when the length is 8 ft. this distance is 18 in. It is convenient to measure these lengths by means of marks scored across the pick handle.

Neatness Essential.—There is a wide difference in the methods used in the renewal of ties. Many foremen do this work in a neat and orderly manner, and the appearance of the road is not impaired. Other foremen seem to endeavor to make the road look as untidy as possible. The same progress is made in the long run by both men. The latter class should study to acquire neatness in their work. The

Renewing Ties on Main Line

photograph shows a typical operation in renewing ties on a main line section.

Rules for Number of Ties.—The rules of the Pennsylvania provide that, for yards, storage sidings and commercial sidings, 14 ties shall be used to each 33 ft. of track; for main tracks, on branches with light traffic and in running side tracks, 16 ties; for main running tracks, on branches with

medium freight and passenger traffic, 18 ties; and for main running tracks of heavy freight and fast passenger traffic, 20 ties. If necessary the number of ties may be increased on curves.

Ties of fourth and fifth class dimensions shall be used in all running tracks as the traffic may require. Ties of third class dimensions and lower shall be used in tracks other than running tracks.

Rules for Spiking.—On tangents with or without tie plates and on curves where tie plates are not required, one rail holding spike inside and one outside are to be used at each tie along each rail, and on curves where tie plates are used, ordinarily one rail-holding and one plate-holding spike inside and one rail-holding spike outside; when necessary, on account of high speed or heavy traffic, a fourth spike may be added for plate-holding outside.

It is required that care be taken to keep spikes driven home, and when respiking is necessary standard tie plugs must be used.

Rules for Selection of Wood.—The following rules determine the selection of ties in renewals:

(a) Use treated ties where renewals become necessary through decay alone.

(b) Use pine ties only in such places when treated ties are not available.

(c) Use chestnut and cypress ties in such locations only when neither treated nor pine ties are available.

(d) Use white oak ties where renewals become necessary through wearing out, rather than through decay.

(e) Do not use chestnut or cypress ties in rock or slag ballast because the tamping will wear out the ties quickly.

(f) Use the oldest ties first, provided all are of one kind. If of various kinds, use white oak within one year, pine or chestnut within 18 months, and cypress within 2 years.

45. Rails

Improvement in Method of Manufacture.—The essential function of the two rails of a track is to bridge the spaces between the cross-ties. The rails carry the rolling load occasioned by the traffic somewhat after the manner of the

continuous beam. Only through poor maintenance of the track or equipment is there greatly increased stress due to impact, which is the effect of suddenly applied load. The weights of locomotives and loaded cars have advanced so rapidly, and the speed of the movement has been so much quickened, that increase in the weight of the rail alone was not sufficient to meet the demands made upon it. Improvement was therefore required in the method of manufacture, composition, design of cross section and degree of maintenance. The first step was the introduction about 1906 of the open hearth process into the manufacture of steel rails. The use of this process increased rapidly, and in 1910 the Bessemer and open hearth processes were about equally employed. The rails now used in main tracks are largely manufactured by the latter process.

Change in Carbon Content.—The carbon content of rails next received attention, the present specification of the Pennsylvania, adopted in 1908, requiring an average of 0.5 per cent of carbon in Bessemer and 0.75 per cent in open hearth steel. The newer designs of the rails arose from the necessity of not only a greater support for the heavier loads, but also an increased wearing volume of the head. Thus, the 130-lb. P. S. section rail has a height of 6½ in., with the width of base 5½ in., the increased overturning moment being resisted through the invariable practice of using tie plates under such rails. The width of the head is 3 in., which is 20 per cent greater than is employed in either the 85- or 100-lb. sections.

Maintenance.—The maintenance of rail is dependent not only upon the lining and surfacing given it, but also upon the number and soundness of the ties, the depth of clean ballast, and the sufficiency of the roadbed. The rules cover the handling of the rails, the placing of them in track, the inspection for defects, and the reporting of failures. The features in the specifications which relate to drop test, discard in the ingot, manner of straightening at the mill, etc., are of academic rather than practical interest to the trackman. For the proper recording of rail fractures, however, the practice in branding and stamping rails at the mills, which is

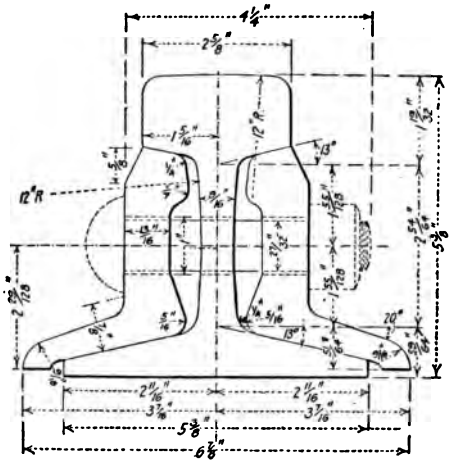
given in some detail farther on, becomes necessary information.

Handling New Rails.—The manner of handling rails, both in unloading them and in storing them for future use, is important enough to have definite rules laid down for its performance. It is specified that an approved loading device shall be used in depositing the rails from the cars upon the roadbed, and it is also required that this work shall be followed by placing the rails base down parallel with the track and with a uniform bearing upon the bed. This is not alone from consideration of neatness, but because in this position the rails can be inspected as regards their ends being square, and any crooked ones can be noted. The bent rails should be carefully straightened with a rail bender before putting them in the track, and the others should be sawed off square. If splices are distributed with the rails they should be placed neatly at the ends of the rails.

Use of Rails Shorter Than the Standard.—No rail less than 12 ft. in length is allowed in a main track, although these may be laid in yard tracks. If a considerable number of rails shorter than the standard are to be used in main track, it is preferable that they be placed on tangents and the several lengths kept together as far as possible. These odd lengths can be employed to good advantage in switch work, using only standard lengths in the main-track parts of work. Emergency rails should be stored at suitable intervals along the road and, for both neatness and availability, should be placed on fixed supports above the ground surface. When any of the rails are used their places should be promptly supplied.

Arrangement of Joints.—The rules of almost all roads require that the rails shall be so laid in the track that the ends of the rails on one side will be opposite the middle of the rails on the other side. Formerly some roads specified that the joints on the two sides should be opposite, but this practice has virtually disappeared. With the use of standard 33-ft. rails and the acceptance of 32-ft. special lengths, the maximum variation on curves need not be greater than 6 in. If 30-ft. rails should be the next special length, a variation of 18 in. might be permitted. The joints through switch

connections may be staggered as little as 3 ft. when necessary, but a greater difference is desirable. Joints should be kept out of switches and guard rails, and they are avoided



A. R. A. Type B 100-lb. Rail and Splices

at road crossings by the use of longer rails. Compromise or step joints, which are those connecting different sections and weights of rail, are not permissible in crossings, through switches, or upon trestles, viaducts or open floor bridges.

Bolting at Joints.—The full number of bolts should always be in place at the rail joints and they should be kept tight. To facilitate the tightening of the bolts they need to be oiled occasionally. Except where the rails are of less weight than 70 lb. per yard, half the bolts should be turned in the opposite direction, while on rails lighter than 70 lb. the nuts must all be placed on the outside.

Manner of Spiking.—The rails should be full spiked to the tie, the detailed requirements in this respect having been indicated in the article on ties. The spikes should be driven straight and not bent over to grip the rail base. They should not be set closer to the edge of the tie than 2 in. To avoid slewing of the tie, the inside spikes should be directly across from each other and similarly as regards the outside ones, with the further requirement that these shall be in advance of the inside ones in the direction of traffic. Except

on bridges, trestles and viaducts where ballast is not used, the slot holes of splices, both inside and outside, should be fully spiked, this provision being necessary to prevent creeping of the rails.

Expansion Openings.—The openings between the ends of rails are specified for different temperatures, which should be obtained with a standard thermometer. The spacing can best be secured by inserting steel shims of the proper thickness between the ends of the rails, the shims being removed before trains are permitted to use the track.

The opening between the ends of 33-ft. rails for the different degrees of temperature is as follows:

From 10 deg. below to 14 deg. above zero—$\frac{5}{16}$ in.
From 14 deg. above to 38 deg. above zero—$\frac{1}{4}$ in.
From 38 deg. above to 62 deg. above zero—$\frac{3}{16}$ in.
From 62 deg. above to 86 deg. above zero—$\frac{1}{8}$ in.
From 86 deg. above to 110 deg. above zero—$\frac{1}{16}$ in.
Above 110 deg. rail to be laid close without bumping.

Precautions Against Buckling.—When the rails become very tight, there is danger of the track buckling sufficiently to cause derailment and a shorter rail should be inserted before this can occur. The track should also be kept filled with ballast to within ½ in. of the top of tie as a further precaution against buckling. A judicious use of rail anti-creepers, by reducing the tendency toward creeping, modifies the danger from this source.

Rail Defects Which Lead to Failures.—Track foremen and watchmen should examine the rail in the track frequently and carefully for signs of damage or defect. Some of the more common kinds of failure are given, together with the indications of defective condition. Splitting of the head is evidenced by a black streak along the top surface, and splitting of the base by rust streaks at the juncture of the web and the upper side of the base. The latter kind of failure produces what are known as " half moon" breaks, which are liable to result in a complete failure of the rail. Piping of the rail is a dangerous condition and may be distinguished by a flattening of the head at the middle, and a breaking down of the under side of the head, diminishing the width of the space between the head and the base. By close observation a piped rail

may be discovered before it has progressed to the stage where failure is eminent.

Nicked or dented base or head from a broken wheel, burned spots on the head from slipping of driving wheels, and other similar defects, should be looked for carefully. When the foreman considers the defective rail unsafe for traffic, it should be removed at once; if he considers it not immediately dangerous, he should report it to the supervisor; although it is always better to err on the side of safety.

Determining Cause of Failures.—Great care should be taken in determining the cause of a rail failure. Every fracture should be examined carefully to see if internal transverse fissure is present. When such is the case suspicion is thrown upon every rail in the heat to which it belongs, and they should be removed from main track and used only where their failure would entail no serious consequences. A rail that fails should be held for a time, as it is sometimes desired that pieces showing both sides of the fracture shall be sent to the main office for observation and test. The heat number and letter of the fractured rail should be correctly ascertained in every case.

Branding and Stamping of Rails.—The brand on rails gives a number or abbreviation by which the rail section is designated, the name of the manufacturer, the month and year of manufacture, and, if the metal is open hearth steel, the letters "O. H." are added. Square block letters and figures about an inch high are commonly used, and the brand will always appear **slightly raised** at regular intervals on the web of the rail. The month is generally shown by Roman numerals, as VII for July and sometimes by a series of I's, as IIII for May.

The number representing the heat, blow or melt of steel, and the letter to indicate the position of the rail in the ingot, are stamped on the web of the rail with dies while it is still red hot, but after it has been completely rolled and sawed to length. All mills except Pennsylvania and Colorado stamp the heat number and letter on the side of the web which does not carry the brand. Remembering also that the brand always appears in **raised letters,** and that the heat number and letter is **stamped on,** no confusion of the two should exist.

The heat number may be repeated several times on the rail length, or it may be shown only once or twice, according to mechanical conditions of the mill. The letter showing the position of the rail in the ingot is sometimes stamped on by hand, in which case a die is held on the web and struck with a hammer; but generally it is applied by the same or another machine that stamps the heat number. Sometimes there is a letter in front of the heat number to indicate a furnace, and this should not be confused with the rail letter, which follows the heat number and is stamped by the same machine. Typical stamping would be B18945 C, which would mean the C rail from a particular heat and furnace.

46. Ballast.

Function of Ballast.—Ballast is to the track what the foundation is to a house. It forms the support for the track structure which in turn carries the weight of the traffic. A different degree of support is needed for the several kinds of traffic. Where the traffic is light and the trains few and unimportant, dirt ballast may answer. If the traffic is heavy and moved at a moderate rate of speed, chats, gravel or cinders are generally sufficient. When the freight trains, as well as passenger trains, are frequent and all are scheduled at high speed, stone ballast is required.

The essential functions of the ballast are: To distribute the load upon the roadbed, to drain the water from the track, and to supply the means of maintaining the surface and line of the track. To accomplish these objects the ballast must be of proper depth, of good quality and clean. Unquestionably the best ballast from the standpoint of support is stone ballast. By an increase in the depth of such ballast a practically unyielding support may be obtained for the heaviest movements. The maximum depth of ballast where no sub-ballast is in place is 24 in.; if a sub-ballast is used a depth of 12 in. for each is favorable.

Sub-Ballast.—The sub-ballast serves the purpose of a cheaper and equally efficient base for the ballast bed. It is usually of cinder, but may be of gravel or screened slag. Granulated slag is not desirable for either a sub- or top-ballast. The additional thickness of ballast insures the road bed being

drained to a greater depth than would otherwise be possible. Since effective drainage is one of the essentials of track, the addition of a sub-ballast is justified wherever the soil does not allow free percolation of water. The clays, shales and gumbo soils are always troublesome when in direct contact with the ballast. If a sub-ballast was not supplied in the original construction, it may be had by first raising the track upon cinders, and then applying the ballast.

Cleanness Essential.—The cleanness of the ballast largely determines the economy of the track maintenance. If the ballast is of cinder, it requires renewing from time to time. When it becomes old and "lifeless" it will not support the traffic, and will not drain the water. The winter surfacing over such ballast is very expensive of labor. The remedy is to dig the material from the track and then raise it if possible from 4 in. to 6 in. on fresh cinders. Ashpan cinders are preferable for ballast, although hard coal ashes are not unfavorable. Front end cinders should generally be used for some other purpose than ballast.

Where stone ballast is in use it must be kept clean for effective drainage. Even the hardest trap rock will ultimately crush under heavy traffic. The cinders thrown from the stack, as well as those dropped from the ash pan, tend to foul the ballast. When the water can no longer pass through, "pumping" results and maintenance is rendered more difficult. If frequent surfacing is done the process in itself aids in keeping the track clean; and if the tie renewals are properly conducted that operation may also be made a means of cleaning the ballast. There is still needed, however, a periodical forking of the stone, especially of the ditches on multiple-track roads.

Cleaning of Center Ditch Not Always Required.—The cleaning of the center ditch on a double track road is seldom justified. It is not required for drainage, since the water should in all cases be shed at once to the sides. If the ballast in the center space is open to receive, and consequently to hold the water, there will be a tendency to soften the bed beneath the inner lines of rail; although, the top course of the ballast in the center ditch may well be kept clean for appearance. The cleaning of the ditches on a four-track road is necessary to allow the water to pass through them and thus reach the side

ditches. There is no question of the advantage from keeping the ballast in the track and shoulder clean at all times.

Ballast Supply.—Ballast must be supplied according to standard specifications and the kind to be used at various points will be determined by the division officers. It is desirable that a uniform flow of the material be maintained throughout the season of renewals, so that the full needs of the repairs may be met. It is required that enough ballast shall be available to fill the track ½ in. below the top of tie, and especially that the track shall be kept filled at all times at joint ties and at ties where rail anti-creepers abut. It is further specified that in renewing or respacing cross ties, in raising track or cleaning ballast, sufficient back filling must be done to hold the track in proper line. The photograph shows a section of four track road with the ballast leveled in accordance with standard requirements.

Ballast Border.—Pennsylvania standard plans of roadway give the width and depth of ballast border for the different track systems. For single track the distance from the gage is 4 ft. 6 in., and the distance below the top of the tie 17 in. For

Ballast Leveled to the Standard Section

double track the depth is also 17 in., but the distance from the gage is 4 ft. 8 in. For a four-track system, with 18 in. of ballast below the bottom of the tie at the center of the outside track, the distance from the gage is 5 ft. 3 in. These figures are based upon a slope of sub-grade of 1 in. in 4 ft., while that on the ballast shoulder is 1 ft. down for 2 ft. out.

On well maintained roads it is permitted to line the edge of the ballast with a board. The placing of the stones in the border with the hand is extravagant and is not permitted. Even on branch roads that are ballasted with cinder a uniform border should be maintained. This makes the road look more tidy and creates a favorable impression upon those who travel over it. It is usual to bring the road to its best appearance after the summer work is done, and it will thus present a neat appearance throughout the entire winter.

Removing the Ballast for Snow Handling.—It is not desirable to disturb the track after the season's work has been completed in the fall until the frost has come out in the succeeding spring, except that at the approach of winter the ballast must be removed from the spaces between the ties under frogs, switches and guard rails in order to facilitate the cleaning of snow and ice. Such points will require more frequent inspection during the winter because of the greater tendency of track to heave when insufficiently back filled.

47. Track Fastenings and Accessories.

Rail Joints.—Track fastenings consist of splices, bolts, nut locks and spikes; the auxiliary fastenings, or accessories, consist of tie plates, rail anti-creepers, tie rods, etc. The rail joint is the combination of splices, bolts, and nut locks through which the continuity of the rails is maintained. There are three common types of rail joints; the 1-tie supported joint, in which the splice is over a single tie; the suspended joint, in which the splices rest upon two adjoining ties; and the 3-tie supported joint in which the splices embrace three consecutive ties.

The Splices.—The track fastening wherein detailed design is of the most importance is the splice. The higher impact due to heavier wheel loads have made necessarly a substantial increase in the strength of the joint. This has been attained

in three ways: (1) By enlarging the section, especially in the head of the splice; (2) by bridging the joint; and (3) by base supporting the rail. Joints are supplied commercially which have one, or two, or all of these features.

Pennsylvania's Splice.—The standard splice of the Pennsylvania for all new installations is the Continuous, or base-supported splice. Insofar as the item of sustaining the load is concerned, it is not considered necessary with this splice to space the ties to the former standard of a suspended joint. The splice as now supplied is without provision for slot-driving the spikes, and the duty of holding the rails against creeping is performed by an equipment of rail anti-creepers.

Staggering Bolts.—The practice on most roads requires that for rails weighing 70 lb. and over the bolts must be placed with the nuts alternately outside and inside. To assure that this is always done, the holes in the splices when mated together are oval on one side and round on the other, this condition alternating for the four or six holes of a splice. The upper portion of the bolt is made oval-shaped, so that it will not turn when the nut is being applied, and this also assures that the bolts will only enter the splice in the manner intended. As most types of splices are fabricated to furnish a neat fit with the rail section, the presence of rust interferes with their correct application and with the proper movement of the rails within them under contraction and expansion. It is therefore necessary that the splices be well oiled before being used, and periodically while in service in the track. When newly applied they should be driven home with a hammer after being run over for several days, and the bolts then be drawn to as tight tension as the standard wrench will allow.

Track Bolts.—The bolts in use today are mostly heat treated and oil quenched, and their full section is preserved by immersing them in a bath of oil and storing them under cover for a protection against rust. Since the per pound cost of bolts is 50 per cent higher than that of any other item among track fastenings and accessories, the importance of a proper care of the bolts in use is manifest. If too great a tension is applied in tightening them in the track the bolts will be stretched, the threads damaged and the usefulness of the member in the joint greatly reduced if not lost altogether. For this reason a longer

wrench should not be used than is provided by the standards of the road.

Nut Locks.—The universal means of keeping the bolts tight is through the spiral spring nut lock, of which several patterns are supplied adapting them to various kinds of service. The nut lock requires the greatest strength possible, since full service of the joint is not obtained unless the bolts remain entirely tight. The spring activity of a nut lock is its most important feature, and this is not merely the initial, but the permanent activity of the spring. This property is only obtained by the use of a high quality of steel and by careful heat treatment of the nutlocks.

While the principal function of the nut lock is to keep the bolts from working loose, it is not its only one. There is a continual wear of the bolted parts, as well as a slight stretching of the best of track bolts, both in ordinary service and through overstraining with the wrench, which must be compensated for; and it is recognized that it can best be done in the ordinary rail joint by means of the spiral spring nut lock.

Spikes.—The spikes used by the railroads are of a wide variety of designs, although the spike of 5/8 in. column and 5½ in. long, with a flare both front and back, seems to be the type preferred by the greatest number of roads. By reason of the fact that they are likely to be redriven several times the A. R. E. A. specifications for spikes require a high grade of material in their manufacture.

Tie Plates.—Of the auxiliary fastenings the only one to have a standard design on the Pennsylvania is the tie plate. The thickness provided, viz., 11/16 in., is sufficient to avoid buckling even under the heaviest traffic loads, provided only that the tie plates are applied properly. The tie plates are now made without a bottom flange, and the omission of this feature, once thought to be indispensable, has come to be recognized as of no disadvantage, but probably of some little incidental benefit, through the avoidance of one cause of decay in the tie, the cutting of the fibres of the wood. The established rules governing the installation and maintenance of the several items in track fastenings and accessories follow in their due order.

Maintenance of Joints.—The joint ordinarily is the weakest part of the track support. In the article concerning ties and that relating to rails, certain points were stated regarding the maintenance of joints. These will not be repeated, but in order to cover this important subject more fully some rules are given which are stated elsewhere. It is specified that the inter-tie spaces at joint ties, and at ties against which anti-creeping devices abut, shall be kept filled with ballast at all times. The requirement that care must be taken to keep spikes driven home, is especially necessary at joints. In raising track the lifts must be so regulated that the splice bars will not be bent or the joints strained.

Renewal of Splices.—All broken or badly cracked splice bars found in main running tracks should be replaced immediately. The renewal of broken splices is a live source of danger, and it is desirable that wherever practicable this work shall be attended to by two men. When it is necessary to renew both splice bars at the same time, the operation requires flag protection. To facilitate the study of splice bar failures a record should be kept of all broken splices removed from the track. The correct maintenance of compromise joints also is essential to the safety of the track. The kind furnished does not always provide for a smooth running surface or a continuous gage line. When the offset either in the surface or the alinement exceeds ⅛ in. a defect is created which is not entirely safe. Especial watch should be kept upon all compromise joints to see that they remain in good adjustment.

Tightening Bolts.—It is important that all the bolts be inserted at rail joints and that they be kept tight. They must never be strained in performing this work, and it is therefore forbidden to use a pipe extension to the track wrench. To facilitate tightening them they must be oiled occasionally. Loose bolts not only constitute a definite defect, which may eventually increase to a dangerous stage, but the noise from this source is objectionable and the riding of the track is rendered inferior.

Maintenance of Bond Wires.—In applying bond wires in automatic signal territory it is desirable that the holes be as close as possible to the neutral axis of the rail section, but it is permissible to have the holes drilled on either side of the

neutral axis, provided such drilling comes within the vertical limits of the bolt holes. The drilling of holes in the base of the rail is a known source of rail failure and is not allowable. The use of bond wire protectors as an efficient means for preventing bond wire failures should be extended. The signal maintainer, or in some cases the track walker, is required to test all wires periodically.

Special Maintenance Required at Insulated Joints.—The weakest of all joints is the insulated joint. The ties under such joints should be of the best, and they should be tamped whenever they begin to get low. If the ties are loose the fibre wears out quickly, and this may cause a failure of the signal. The low joint not only causes rough riding of the track, but, of greater importance, it contributes to the chance of a rail breaking within the block joint, which might cause an accident. The track foreman is required to see that insulated joints are well maintained and that all broken bond wires are repaired promptly. He must also see that the rails and splices in bonded track are kept free from contact with ballast or dirt, which in an extreme case might cause a signal failure.

Examination of Joints for Defective Rails.—It is a good rule for the foremen to examine in detail all insulated joints at least twice a year. It will thus be seen whether the insulation is good and whether any rails have cracked. Only full length rails should be used at block joints, because if one should break a duplicate could be obtained more quickly. Also the best material is in the 33 ft. rails and they are the least likely to break. It is proper to make the opening between the rails at a block joint ½ in., which requires the use of two end posts and to maintain this by an ample use of rail anti-creepers. A wider joint opening tends to make rough-riding track, and the use of but one end post for obtaining a narrower opening is of doubtful propriety, since the single fibre might crush and bridge the current, causing a signal failure. To avoid an undue wear on the end posts, it is forbidden to place the cut end of a rail within a block joint.

Renewing of Block Joints.—When a new block joint is being put on, it is necessary to raise the spikes of several adjacent ties. Care should be taken that they remain in place,

so they can be driven down quickly before a train arrives. When work is done that interferes with circuits the signal repairmen must first be notified. The track walker should tamp the ties under insulated joints frequently. The foreman should see that good joints are in use, the bolts kept tight and the ties well tamped.

Rules for Use of Tie Plates.—Tie plates should be used on all curves of 2 deg. or over in running tracks and 6 deg. or over in sidings; also on all switch ties, and ties on turntables, ash pits, bridges and trestles; at water stations and track troughs, and through all road crossings and station platforms. On tangents and curves of less than 2 deg. in running tracks or 6 deg. in sidings, when the annual tonnage is less than the figures shown in the table below, tie plates need not be used; when the annual tonnage equals or exceeds the amount shown tie plates must be used. These rules in effect require the use of tie plates in all main tracks of main lines and of heavy tonnage branch lines and in the curves of many sidings as well.

ANNUAL TONNAGE REQUIRING TIE PLATES

Untreated Ties	Million Tons	Treated Ties	Million Tons	Treated Ties	Million Tons
White Oak	8.5	Red Oak	5.1	Red Gum	2.6
Black Locust	14.7	Honey Locust	5.1	Soft Maple	2.6
Black Walnut	6.8	Hickory	5.1	Butternut	2.6
Black Cherry	6.4	Hard Maple	5.1	Elm	2.6
Chestnut	3.6	Hackberry	5.1	Short-Leaved Pine	2.6
Sassafras	5.5	Ash	5.1	Long-Leaved Pine	4.5
Red Mulberry	6.4	Beech	3.6		
Long-Leaved Pine	7.5	Sycamore	3.6		
Bald Cypress	4.2	Black Gum	3.6		

Types of Tie Plates on the Pennsylvania.—Two types of tie plate are in general use on the Pennsylvania: the standard tie plate for cross ties and switch ties, which is 7 in. wide by 10¾ in. deep and 11/16 in. thick; and the bridge tie plate which is made 9 in. wide instead of 7 in. to cover more fully the wider ties employed on bridges and trestles. Both types of tie plate have punching to render them suitable for use with all weights and sections of rail between 70 lb. and 130 lb.

Application of Tie Plates.—It is required that all tie plates shall be applied in a neat and workmanlike manner. The absence of a bottom flange makes only ordinary care in spiking needed to draw the tie plate to a snug contact with the outside of the rail base through the extent of the shoulder. Where required to furnish an even bearing for the tie plate the tie may

be adzed, but this should be no more than is necessary for the purpose. It is forbidden to drive the tie plate into place with heavy blows, as this practice not only causes damage to the tie plate but injures the surface of the track. The tie plate should be centered upon the top face of the tie as nearly as possible. When one or two plate-holding spikes are permitted, these should be the last driven, as thus the tie plate may be drawn to a satisfactory adjustment with the rail. The shoulder of a tie plate should never be allowed to extend under the base of the rail.

Use of Rail Anti-Creepers.—These track accessories are economical where creeping of the rails occurs, due to causes other than poor maintenance, but are extravagant and wasteful where their use is not required. The rules specify simply that rail anti-creepers may be employed where ncessary. They should generally be placed upon the rail opposite the joints when these are slot-anchored; or upon both rails, when the joints are not so held. It is especially required that both lines of rail shall be anchored in one way or another upon the same ties. The use of anti-creepers at intermediate points is permitted when conditions warrant. Their use is forbidden upon grades ascending with the traffic, except at the approaches to interlockings. They are useful under all circumstances at the approaches to drawbridges and stations, particularly when the track is on a curve, and they are indespensable upon both drawbridges and turntables. Many derailments at frogs in yards are avoided by anchoring the two lines of rail which end at the switch points against creeping.

Maintenance of Rail Anti-Creepers.—To supply the maximum benefit from their use anti-creepers should be properly applied and their correct positions maintained by the track walker. A glance will show when there is not a good bearing against the tie, and a light tap with the hammer will determine whether or not the anti-creeper has become loose upon the rail. When new ties are put in, or the existing ties respaced, care should be taken to move the rail anti-creepers into their proper places against the ties. If ballast is in contact with the device throughout the winter it is likely that some of them will need adjustment in the spring. The requirement that the tie spaces where rail anti-creepers abut shall be kept

well filled with ballast does not imply that the ballast should involve the anti-creeper. When the rail moves back because of contraction the anti-creeper may be dislodged altogether if the ballast is too full.

Tie Rods and Tie Spacers.—Tie rods are useful for holding the gage of the sharper turnouts and tie spacers for keeping the ties carrying ground connections from becoming displaced. The rules do not specify the manner of employing either tie rods or tie spacers, but good practice requires that both be used economically. The tie rod most commonly used has a turnbuckle for drawing the rod up to the rail. Unless done carefully this operation may cause a dangerous tightening of the gage, to prevent which it is well to have a track gage in place while the rod is being put on. The most common use of tie rods is to hold the gage at joints on a curve, particularly where the rails have not been curved beforehand. Their use on tangents is seldom justified.

Tie spacers are particularly effective in holding the ties in the vicinity of the point of switch against slewing. Such a defect would cause lack of adjustment in the switch which might lead to an accident. This device is also of use on bridges and trestles where a wooden guard log is not used, or is temporarily removed. The employment of spacers where bell cranks or other interlocking parts are anchored is also quite favorable. Their use should be with due regard for utility, and they should not be applied extravagantly.

CHAPTER XIII

PRACTICE IN RAIL RENEWALS

48. Laying Rail in Main-Line Tracks.

Planning the Work of Renewal.—On lines of intensive operation, where the available intervals between trains are never more than 30 min., and where intervals as low as 15 min. must frequently be utilized, it is of the utmost consequence that the detail of the work be planned to the last item. No single operation must be omitted that can be completed before the track is broken. To delay the cutting of a closing rail until after the relaid rails are in place is entirely out of the question, and this rail must be provided for beforehand after a careful determination of its length with a steel tape. The number of rails that can be laid in a given interval must be known, and although this is somewhat variable it will be found for 100-lb. rail close to a rail a minute for intervals between 15 min. and 30 min. To attain this performance the rails must be as near the place where they are to be applied as possible, and all needed material must be close at hand.

Removing or Shifting the Tie Plates.—In renewals of this character the preliminary work largely determines the efficiency of the operation. In the event that rail with a different width of base is to be laid and the tie plates can be dispensed with temporarily, the first work upon the arrival of the relaying gang is to remove them, the ties that were without tie plates being adzed down when these are in the minority and those surfaced up that carried tie plates when they are in the minority. When the tie plates may not be removed, as is the case with many of the newer rail sections, but require shifting, as occurs when a rail with a wider base or head is to be applied, this work should only be done upon the alternate ties on a single line of rail in advance of the relaying. Even then a full spiking of the rail is required except for a limited number of train movements. There is nothing gained by shifting the tie plates on the other line of rail because, through

varied wear in the old rail, good gage can only be obtained by gaging along with the renewal. After this work has been done the detailed surface of the track must be given attention, so that the new rail will lie upon as smooth a bed as possible. The ties must also be adzed to provide a level seat alongside the rail.

Fixing the Point of Beginning.—The point of beginning must be determined, and where possible this should have special regard for the existing locations of block joints, when these cannot be changed, so that the introduction of unusual lengths of rail in the main track at isolated points may be avoided. If this should necessitate laying the rail against the current of traffic, temporary rails of the new section may be used, so that the approach ends of the permanent rails will not be injured.

Preliminary Tie Spacing.—The rails are then strung out just outside the ends of the ties to indicate the new positions of the joints for use in the preliminary tie spacng. This method is not accurate on sharp curves, and the position of the joints must be determined in such cases by a careful measurement with a steel tape after the average length of the new rails has been carefully ascertained. When the rails are set up for the purpose named it would be an unnecessary refinement to use shims and many of the shims would surely become lost. It is quite satisfactory to place a number of the rails, five in summer weather, with their ends in contact, and separate each five with a spike, which represents the aggregate of the several spaces.

Attaching the Splices.—When rails are to be laid one by one, especially if the Continuous splice is employed, a considerable saving in time is effected by attaching a joint to each rail at the advance end in the direction of relaying. The joints are held in place by a single bolt which is left loose to permit of the splices being separated for the ready admission of the next rail. Also when there are insulated joints in the stretch being relaid, these are applied in advance to the two rails which are then put in as one.

Providing Necessary Protection.—When the preliminary spacing has been completed, if it is required for insuring that the flanges of the splices will enter without exception, and

when the tie plates have been shifted, if this is necessary, the word is given and the men line up to await the foreman's signal that use of track has been obtained, communicated from the telephone box or from a field telephone connected with the despatcher's telephone line. The principal protection is that which is afforded through flagmen sent in each direction, who not only display a red flag but place torpedoes on the rail. In automatic signal territory the signalman, whose duty it is to bond the track, as a further protection shunts the track circuit by means of a wire so as to present the stop indication at the nearest signal; a large red banner is placed at each end of the stretch being relaid; while at the immediate location of the work the foreman's red flag is always held fully displayed in his hand while the track is broken.

Quickness of Action Essential.—There is no item of work wherein the matter of organization is of such importance as

Main Track Relaid with New Rail

that of rail renewal, which of necessity causes repeated breaking of the track. The distant flagmen must be trained to receive instantly the foreman's signal to begin protecting and must respond just as promptly when the signal is given to withdraw. The need for immediate action by the entire force

is not the less insistent. A specific duty is laid upon each member of the gang and remains for every operation, so that no further lineup is required. Maintenance rules generally require that the rails shall be laid one at a time and similarly forbid the pulling of more than half of the spikes, or the removal of more than one bolt from a joint in advance of the renewal. This severe but necessary restriction can only be met by perfect organization.

Detailed Operations in Relaying.—The bolts at the joints to be broken have washers added until the nut has just a safe hold. Two of the best workmen are assigned to each end of the run to be relaid. Ten men with claw bars are delegated to remove the spikes from the chosen side of the rail. When this is the outside, the spikes may have been previously started to assure their coming out readily. Eight men with lining bars push the old rail aside, two dislodging it, one guiding it across the new rail and five lining it away. When a new rail of heavier base is being laid against the inside spikes two men with claw bars must follow closely the men throwing out the old rail to raise the spikes sufficiently. Four men come after these, of whom two with spike mauls and punches drive down the butts of broken spikes, one with an adz completes dressing a seat for the rail, and one with a stiff broom sweeps aside chips of wood, pieces of ballast and spikes. Sixteen men with tongs put the new rails in place as fast as the old rails are removed, and 10 men working in pairs complete the application of the splices, inserting at least half their complement of bolts. Two men push the rail under the spike heads and spike the joints and centers, while the 10 men who were pulling spikes, but who are now free, spike the rail upon every other tie. The four utility men put the cut rail in place and look after the compromise joint in case a different section is being laid. The gang which threw out the old rail completes the full spiking and the men who set the rails in assist in applying the remaining bolts, giving them all as full tension as possible. This force of men generally consists of two gangs, and, in addition to the foremen and their assistants, numbers about 60 men.

49. Laying Rail in Branch-Line Tracks

The Practical Force.—On most branch roads a large organization for laying rail is neither necessary nor generally practicable. A single track branch, with a morning and afternoon passenger train in each direction meeting each other about the middle of the branch, and with a local freight train and five or six other extras in the working period, may be taken as a typical example. The sections are 4 miles in length, and each has a force of 7 men, not counting the foreman. Intervals as low as 30 min. would be used, and some as high as 3 hrs. might be had, the most common period being 1 hr. The available force for laying rail will generally be a combination of four section gangs totaling 28 men; although on roads of this character the use of extra gangs for this work is not unusual, the organization being the same in both cases. Renewals are almost always made by applying a heavier section rail removed from the main line. In past days when maintenance was inferior and rail in main lines, equally with that in branches, was allowed to become battered at the joints, it was desirable to lay the fit rail without change in the original mating of the rail ends; but with improved maintenance and a higher standard of main-line track, this practice is not now required and is in fact seldom followed.

Preparatory Work.—The preliminary work when the combination forces or the extra gangs arrive is to set the rails end to end and in the upright position on the side of the track in which they are to be laid. The spikes are then withdrawn from each alternate tie on both sides of the single line of rail that is to be renewed first. The practice of withdrawing at one time the spikes from the same ties on both lines of rail is forbidden because of the possibility, remote though it may be, of the men, through error, pulling the spikes on the wrong set of ties. This has been known to occur and at least one recent derailment of a passenger train was due to this cause. The other preliminary work is the removal from the joints that are to be broken of all the bolts except two. If the expected train is delayed a limited number of bolts may be taken from the remaining joints, as the disconnecting of the removed rail is done soon after the renewal in any case. The flagmen are not

sent out until the last train has arrived, because curves frequently hide them from view, and their instructions must be positive to flag every train until called in. To avoid loss of time in going to a somewhat distant telegraph office, it is frequently the practice to open a temporary office at the place of renewal; and this is preferably done when the distance to travel is greater than ½ mile.

Protection.—When the use of the track is obtained men with red flags are sent in each direction a sufficient distance to stop a train before reaching the obstruction. They are also provided with torpedoes which they place on the rail in the manner specified by the rules. Any train allowed to proceed into the block where the track is broken is given a message to look for flagmen protecting for rail renewal; although omission to do this would not lessen the responsibility of the track force. At the ends of the stretch being taken out additional red flags are placed.

Detailed Method of Renewal.—The detailed operation of relaying will be as follows: One man removes the two bolts at the joints to be broken; 4 men pull all the remaining spikes from the stretch to be removed; 3 men line the old rail aside; 1 follows close to knock the old tie plates off the ties; 12 men with tongs set the relayer rail in place and 4 men start putting on splices; the 9 men who preceded the gang setting in the rails being now free, start in squads of three with bar and track gage putting on tie plates and spiking the relaid rail to gage at the joints and upon every third tie between; the 12 men who put the rail in place complete the spiking and bolting, while the 4 men who followed them cut a rail and put it in place for closing up the run, and also apply the compromise joint. When the flagmen are recalled every tie has been equipped with a tie plate and fully spiked and all the bolts are inserted and made as tight as possible. An average performance in laying rail by this method will be 15 rails or 500 ft. laid in 1 hr., or 50 rails or 1,650 ft. of rail laid in a day.

50. Replacing Tee Rails With Girder Rails

Where Girder Rails Are Required.—The principal use of girder rails is for the tracks in paved streets or at other points

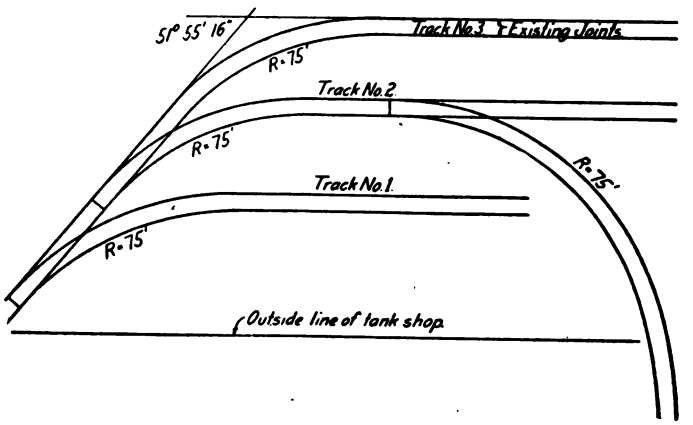
where paving is required, but they are sometimes placed where the advantage of the rolled guard rail forming a part of the design may be utilized for guiding the wheels through sharp curves, even though no paving is done. In past times a makeshift paving has been obtained with tee rails by the use of shallow paving blocks or by means of wooden cross blocks on top of the ties; but this construction has been found unsatisfactory and the tee rails are being replaced with girder rails in many such places.

Locomotive Crane Desirable.—Special problems are presented in such renewals since they usually occur in busy yards where the service is heavy and only capable of suspension during brief periods. The work frequently is complicated by the presence of curves and switch connections, the members of which when of the solid manard type are too heavy to be handled economically by men. The use of a locomotive crane in such cases is a practical necessity. This is especially so where there are curved rails which may need to be turned about. In renewals of this character it is always desirable to install the new work on a bed of new stone ballast in line with the present practice of providing a substantial roadbed wherever the service is heavy.

The Survey.—The first and most important work is the survey, establishing the line in precise agreement with the manufacturer's general plan of the layout, and also fixing the desired grades of the several tracks. The difficulties in the way of accurate instrumental work may be many, but the survey should be continued until the data of the plan are exactly met. It is a mistake to assume that special work will adjust itself, for even a slight variation in the early stages will seriously affect the succeeding work, not only as regards the mathematical problem but also the physical detail which will later have an effect upon the wear on the rails and the movement of cars. The renewal of the layout shown in the sketch, in which 9-in. girder rails replaced 85-lb. tee rails, will serve to indicate a practical method of procedure in similar cases.

Special Requirements.—It was determined to install the work on a 6-in. bed of new stone ballast in place of the

wornout cinders under the old tracks. The ties were to be renewed out of face, using creosoted ties laid on 22-in. centers, or 18 to a 33-ft. rail. The track was to be tamped as soon as laid to a uniform grade and in true level. It was especially required that no kinks or tight gage should occur at any point. The renewal in track No. 3 had to meet the



Layout of Industrial Yard

joints in the existing girder rails; the line of track No. 2 had to conform to that of the track entering the tank shop; and the position of track No. 1 was exactly determined by the piling spaces required on either side.

Details in Renewal of Connections.—The installation of the first two switches necessitated suspension of the movement, and these switches were therefore renewed while the plant was idle between Saturday noon and Sunday evening. A locomotive crane was stationed on track No. 1, to deliver and place the switches, mates, frogs and rails; a car of new ballast was left standing on track No. 2; and an empty car was set on track No. 3 to receive the old ballast. To facilitate the assembling of the switch ties a temporary curb of 4-in. by 6-in. timbers was laid along the straight side of the turnouts. Upon it was indicated the exact location of the ties and their several lengths, so there was no confusion or delay incident to placing them.

Tilting Ties at Step Joints.—The matter of compromising the girder and tee rails throughout the work, to effect the temporary closing, which was necessary on occasion, was a detail that had to be determined. The difference in the elevation of the bottom of the tee and girder rails was four inches. It was found that no harm resulted, either to the track or to the new rails, from tilting the ties this amount. The heavy service prohibited the blocking up of the lighter rail. The compromise joints furnished with the new material were moved forward as the work progressed.

Ballast Renewals.—The usual method of applying the ballast was first to clean out the cribs to a depth of four inches below the bottom of the ties, loading the dirt at once upon a car set at a convenient point. When the use of the track could be spared for a day, so much of it as could be completed was torn up and the remainder of the old ballast loaded on the car. A level bed of new ballast was then spread and the new track laid upon this and closed up temporarily. Care was taken to keep the grade 1½ in. low to permit a final surfacing to the established elevation.

Cutting Rails in Track.—In periodically closing up it was necessary several times to cut a rail while spiked down in the track. This was accomplished most readily by applying upon the free end of the rail, which was blocked up slightly, a steady downward pressure by means of a long wooden lever, while cutting was continued on the top of the head and the base at the required point. In deflecting the track to conform with the slightly changed location of the new work constant use was made of the track jack for the relining in preference to lining bars, the edges of the old paving supplying the necessary heel for the jack.

As a safety measure, the tie rods were not applied until the moment the paving of the tracks was about to be proceeded with. Each of the three switches in the layout was provided with an enclosed spring ground throw. Wheel clearances were made 4½ in. and all work was designed to suit the gaging and contour of M. C. B. wheels. The gage of the track was 4 ft. 8½ in. on the tangents and 4 ft. 9 in. on the curves. Adherence to the established gage was of importance to avoid severe wear upon the channels of the girder rail, as

well as to assure the safe passage of cars through the sharp curves of the layout.

51. Cutting and Boring of Heavy Section Rails

New Problem Presented.—In the cutting of the heavier sections of rail the older method of chiseling and breaking by a fall is not practicable, for it is not possible to put a sufficient number of even the strongest men on the end of such rails to lift them safely to the height required for breaking by a fall. One railroad has forbidden the cutting of the heavier rails except in emergency, and requires that they be sawed, even delegating this work to the mechanical department shops in some instances. For the safety of the men in doing the cutting, goggles of heavy glass with wire protection at the sides should be supplied, the use of goggles of ordinary thickness of glass not being recommended.

Making the Cut Square.—In all cutting of rails it is preferable to score only the perimeter of the base and the lower half of the web. Care should always be taken that the marking for the cut is as nearly square with the axis of the rail as possible. This is most readily attained by using the mill sawed ends of the rail as a guide. With a steel tape held at the junction of the web and base an arc is described across the base and web, alternately on both sides. When the rail is turned base up these two lines are joined, and thus a continuous square cut is provided for. A splice bar laid in position against the rail also supplies a convenient guide for marking the cut.

Varied Methods for Different Lengths.—With the cuts from 6 in. to 6 ft. in length it will be found that persistent cutting into the middle of the bottom of the base, after the rail has been scored as above, will result in the end dropping off in a moderate length of time with a fracture almost equal to sawing. When the cut ends are from 6 ft. to 12 ft. it is better, after the preliminary scoring, to apply the rail bender, giving it the greatest tension possible. Cutting is then continued into the base at the extreme edge on the side opposite the rail bender. If this does not result in fracture quickly, the bender is moved to the other side of the rail, and cutting is done into the reverse edge of the base.

When the rail is to be cut near the middle, the rail, after being scored, is laid on its side within the track with a block supporting each end. By means of a long lever anchored beneath the rail of the track the rail to be cut is sprung downward as much as possible, while the cutting is continued into the web close to the neutral axis.

Contour and Tempering of Cutters.—The dressing of the rail cutters is important, not only as regards their contour but the tempering also. The usual trouble with the cutter is from too hard tempering. Any practical blacksmith can obtain with care the proper degree of hardness. This is best found by trial, but will be seen to result when the tool is heated to a cherry red, and cooled slowly in water to a color a mean between a light and dark blue. It is essential that the contour of the dressed tool shall be as nearly as possible that of the tools direct from the maker. In doing the work of cutting a rail the men should be required to change to a fresh cutter when the head commences to broom, or the cutting edge becomes dulled, as neither safety nor performance attends the use of a poor tool.

Boring Holes.—In the boring of the heavier sections of rail, requiring a hole $1\frac{5}{16}$-in. in diameter, indifferent progress is made with the ratchet drill having an 18-in. handle, even when operated by two men. Better results are obtained by the use of the tool with 24-in. handle worked by one man alone. An effective seat for the ratchet drill is supplied by a splice bar held firmly by two rods, with a hook on one end to engage the base of the applied splice and with a nut on the other backing a single splice bar. This avoids the spiking of the ties, as when a short section of rail is used for this purpose. In the process of boring the holes, water needs to be used frequently to keep the drill bits from becoming hot; but, if they should be overheated through an oversight, they should not be cooled too quickly. The drilling is further dependent upon the correct speed and feed of the drill. When corners of the cuting lips wear away rapidly, it indicates that the speed is too great; if the cutting edges roughen or break out in minute particles, the feed is too great.

Grinding the Bits.—Correctness in grinding the bits is a large factor for efficiency in the operation of boring holes in

rails. Care needs to be taken that the proper surface is provided for the bits which should be as nearly as possible like that of a new one, and especially that the bits are correctly centered and have proper clearance. It is hardly possible to do the grinding as accurately by hand as by using a grinder with the appropriate attachment. When the latter means is employed it is only necessary that care be taken to keep the drill from being overheated in the grinding. If it should become too hot it should not be plunged into cold water. Forcing a bit on a wet grinder produces a similar unfavorable effect.

Cutting and Boring With Torch.—The method of cutting and boring rails by means of the acetylene torch has now been so far perfected that its use is becoming common where the facilities are available. To insure the cut being both smooth and at right angles with the axis of the rail, a guide is made which clamps upon the rail and holds the torch in the correct position. To locate the boring exactly, and fix the diameter of the holes accurately, gages are also furnished which fit neatly in the fishing space of the rail, being different for each of the various sections and drilling. In both operations a proportion of five parts of oxygen to one of acetylene is generally employed, the mixture of gases being regulated in the torch.

Rail Saws and Power Drills.—When rail saws are available they give somewhat neater work in the cutting operation, and while the progres is not as rapid as with either of the other two methods described, the nicety and safety of the work make their use desirable. Electric or pneumatic drills, of which the close quarter type is generally the most effective, supply the greatest efficiency in any boring operation and should always be used when electric or pneumatic power can be obtained.

52. Economics of Rail Repair on Branch Line Curves

Economy Essential.—The question of rail renewal on branch lines is an exceedingly live one at this time, and doubtless will remain so for a considerable period. The high price of steel rails, coupled with an increase of 30 per cent in the section required for growing traffic burden, as well as the necessity of devoting large quantities of steel to recon-

struction purposes, has made the problem a most serious one. It seems probable that the renewals on main line, which formerly were just sufficient to supply the relayer rail required for branch repairs and for new siding construction, will be materially reduced for several years to come.

Limit of Safe Wear.—The extent to which rail wear can progress before the limit of safety is reached is thus one of immediate concern. Heretofore it has been the outside rail of the curve which determined the necessity for renewal. Various arbitrary standards for limit of wear have been suggested in recent years. A definite rule was adopted by the roadmasters in convention, but recently the American Railway Engineering Association was unable to fix an exact standard, although recognizing the fact that a dangerous limit does exist. A half-inch of wear has generally been accepted as the extreme amount that is safe for the high side of a curve; but necessity has shown that three-fourths of an inch is not productive of accident, unless the joints in the opposite rail are badly hammered also. Indeed, the low rail has now become the determining factor in most renewals of rail.

Reducing Renewals.—Since probably one-half the normal quota of rail will have to suffice, it is necessary to study how this deficiency in quantity can be met. It is the practice on some roads to interchange the low and high rails on curves and on others to turn the high rail when it has reached a certain stage of wear. Where the branch renewals have been made with fit rail, neither of these methods is entirely acceptable. It is believed that a better plan is to use the worn high rail to relay the low side, thus limiting the renewal to the high side alone. This has been thoroughly tested through a lean year, on a branch of heavy traffic with curves predominating in the alinement, and the results have been entirely satisfactory.

Frictionless Low Rails.—The only rail laid in this branch for a number of years was fit rail removed from the main line, principally of 100-lb. section. The rail when so relaid had ¼ in. wear and was reversed in relaying. After the low rail had become unfit for main track use the high side was generally worn a further amount, between ½ and ¾ in. The high rail, when moved over to replace the low rail, thus sup-

plied a natural frictionless rail, resulting in greatly increased life for the renewed high rail, which was again of fit material released from main line, while the battered low rail was still fit for use in storage tracks operated at slow speed.

Co-ordinating Speed and Superelevation.—The question of avoiding as far as possible the rapid destruction of the low rail presents a proposition of vital importance. The mashing down of the joints, the rolling out of the head, the surface bending of the rail, are mainly the result of excessive elevation for the usual speed run by the trains; or, what amounts to the same thing, a too slow speed for the elevation employed. The rail renewals are found to be least where the freight and passenger schedules are co-ordinated as closely as possible. On the branch referred to the passenger speed is 40 miles per hour, while the freight speed is 30 miles per hour. The superelevation is ¾ in. per degree, which is the theoretical elevation for a speed of 35 miles per hour. Formerly the branch carried a superelevation of 1 in. per deg., the superelevation running as high as 7 in., while the maximum now in use is but 5½ in. Unquestionably a decrease in the destructive action upon the low rail has resulted from this 25 per cent reduction in the superelevation.

It has been proved definitely that the wear of the rail on the high side is related only remotely to the speed used, and is determined mainly by the amount of friction present. The considerable increase in the wear of the high rail after the low rail has become much rolled out is well known to track maintainers. Similarly, the concrete results in diminishing rail wear on the high side, by employing a narrow head section of rail for the low side is becoming better appreciated. The question may be practically met on most branch lines by the use of the doubly-worn high rail for renewing the low side of the curve. The matter is of especial interest now by reason of the tendency toward an increase in the width of the rail head, 3 in. being the usual width for the heaviest sections.

Effect of Low Joints.—The manner in which the track is maintained plays a large part in the rail economy. If the surface is allowed to remain poor the battering of the joints, especially those on the low side, is hastened. The low joint,

besides being a factor in shortening the life of the rail and a cause of accident, imposes a severe strain upon the rolling stock. The maintenance of the splices is therefore important in this connection. The moment a crack develops in one or both bars the suport is diminished and deterioration of the joint quickly follows. The surfacing of the joints is especially necessary in the fall just before the frost enters and in the spring when it is leaving the track. If this feature is given proper attention much of the destructive effect at the joints will be controlled.

Maintenance of Joints.—The prompt replacement of defective splices is thus a duty not only as a safety measure, but also as tending to conserve the rail. In the same way the tightening of the bolts has an effect by no means negligible upon the rail wear. The condition in which the ballast is maintained further affects the question appreciably. It has even been suggested that the sharper curves on a freight road, particularly those above 6 deg., should be kept in stone ballast, even though cinder may answer the general needs of the traffic over the tangents and lighter curves. Good drainage is of course an essential requirement in the maintenance of any track.

Anchoring Track.—The hammering out of the joints is

Rail Anti-creepers Help to Maintain Expansion Openings

greatly retarded by efficient anchoring of the track. All rail whether new or fit is applied with the specified opening for the temperature, obtained with a standard thermometer. Unless a stable condition of the track is maintained, by keeping the tie spaces filled with ballast and the rails secured against creeping, an uneven joint spacing will result. This condition causes hammer blows at the wider openings which materially shorten the life of the rails. The unequal creeping of the rails has a further effect in tightening the gage, which results in excessive wear in the vicinity of the joints, when these alone are anchored. Under a heavy tonnage, anchoring of the track is justified on single track branch lines equally with multiple track main lines.

CHAPTER XIV

MAINTENANCE OF MAIN TRACKS

53. Track Maintenance on Main Lines

Track Maintenance Defined.—By track maintenance in this connection is not meant the maintaining of the track in general, but only of those features which affect the riding qualities. The subject of this chapter embraces, therefore, the routine corrections in line, surface and gage that are necessary for keeping the track both fit and safe for the passage of trains at the established rates of speed. While lining is usually stated first, the more important feature is good surface; for when this is lacking, the line or gage will not remain correct, and without all three the track will not ride smoothly.

The essential reason for all repairs of the track is that the trains may run smoothly and with safety. Even where no passenger traffic is carried, it is still necessary to have a smooth roadbed, for if the track is rough, severe strains are put upon the locomotives and cars, and there is also the possibility of accident. It is not enough that the rails, the ties and the switches are kept in good repair; the line, surface and gage of the road must also be well maintained.

Surfacing Out of Face.—By surfacing **out of face** is meant the establishment of a level condition on straight lines, the application of a regular superelevation on curves and the proper adjustment of the approach and run-off of curves, by working continuously from one point to another. This work cannot be performed without the use of a correct track level and the level should first of all be tested for its accuracy. If the rails show level when the board is laid one way and not level when it is reversed, the proper adjustment of the level must be made by means of the set screws provided for the purpose.

Loose Ties.—Besides the plain irregularities of surface that

are seen upon a casual inspection of the track, there are obscure defects which are not so apparent. Invariably after a stretch of track has been re-tied the new ties become loose, a condition which may not be evident to the eye. It is, however, noticeable in the riding and for this reason foremen should ride over their tracks periodically on fast trains. A loose condition of the ties is one of the most common causes of deficient surface, and care should be exercised to discover and correct the trouble. As new ties which have been newly put in generally require tamping several times before they become settled, it will be found, when renewals amount to one-third or more of the whole number of ties, that a light raise after the replacement will supply the quickest means of establishing a uniform bed.

Keeping Bolts Tight.—Loose bolts are a fruitful source of imperfection in the maintenance of track. The noise caused by this improper condition is objectionable and the element of safety is lessened; but there is a further disadvantage in riding which may not be so fully appreciated. Instrumental tests have shown that the vibrations are noticeably greater over track which has a large percentage of loose bolts. They should be tightened periodically by the entire force, as the work is too considerable for the track walker alone.

Raising Center-Bound Track.—When a test with the eye and the level indicates that the track is good in line and surface and it still rides poorly, the trouble probably is that it has become center-bound and needs raising. Maintenance rules require that the tamping shall not be carried more than 15 in. inside the rail. This rule was laid so that the tie might not develop rigid support at the center, which condition would cause it to rock when trains passed over it. A track with this defect is said to be center-bound.

Light Raise Out of Face.—The only lasting relief for the condition is to raise the track. If the ballast is stone the lift need only be an inch or two, and is generally about 1½ in. Such a lift can be made with the raising bar and does not require flagging of the track. It accomplishes the result quite as well as a greater raise, and is economical both of labor and ballast. When the track is cinder-ballasted the raise should be from 3 in. to 6 in.

Precautions in Raising Track.—Track raising should generally be done against the current of traffic and both rails be lifted at the same time. This is not only the safest way but it is the one which is most comfortable to the passengers. A sufficient run-off must always be made in advance of the arrival of trains. The foreman must not only prepare for the regular trains, but should obtain from the dispatcher information regarding extra trains. In raising track with the jacks they must not be used within the rails, unless this is unavoidable, and the track must then be fully protected in both directions. Whenever possible the raising bar should be used in preference to the track jack.

When heavy lifts are being made there is danger of bending the splice bars or straining the joints. For this reason the track jack should never be applied directly under the joint but preferably in the first crib ahead of it. Also the track is liable to be left too empty of ballast, which might result in buckling of the rails. To prevent this, sufficient back filling must be done to hold the track in line and surface. Especial care should be taken to have the spaces at joints and at ties where rail anti-creepers are applied well filled with ballast at all times.

Taking Out Dips in the Grade.—One reason why good riding is sometimes lacking is the presence of dips or short depressions in the grade. This defect is often overlooked, even by careful foremen. They may wonder why the line does not show up equally well from both directions. Generally it is because of a dip which makes fine lining impossible. These depressions should be surfaced out in the regular program of track repairs. They are especially disadvantageous on curves.

When a piece of track begins to pump it must be given instant attention, as the effect of the churning is to cause further injury to the surface. Such a condition rapidly destroys the riding features of a track, and it is surely an end of the good appearance of the railroad. When it is possible to raise the track, this will furnish the surest remedy. Otherwise the ballast should be cleaned and in either event careful study be given to the curing of the water pockets which cause the trouble.

Maintenance Surfacing.—When only detailed surfacing is being done, such as surfacing low joints, the track level should still be at hand. There are certain to be some rails that require adjustment with the level. In general surfacing the

A Well-Maintained Tangent on Main Line

line rail on straight lines and the low rail on curves are first brought to a proper surface, and the opposite rail then adjusted by a careful use of the track level. It requires skill to sight the rails for this detailed surfacing. If the joint is not raised high enough the work is incomplete, and if raised too high a permanent injury is done the track. Foremen should carefully train their assistants and the first laborer to do this work properly.

The tamping also requires both care and skill, since it is possible, by poor tamping, to raise the rail higher than was intended. This is just as bad for riding as a low joint and is in general respects much worse, because it is a permanent defect. The very worst track condition occurs when a rail on one side is low and just ahead on the opposite side a second rail also is low. This causes a rolling of the train which is very disagreeable. Such a condition on a curve not only produces poor riding but also causes a rapid deterioration of the line.

Lining Tangents.—When the surface has been made true, the repair is not complete until the line is adjusted. The detailed work in this respect can only be done satisfactorily when the surface is correct. If the line is a tangent, or straight line, the foreman should persist in his lining until it is as nearly correct as he can make it. If it is a very long tangent he will often have to be content with whatever result is practicable. When breaks in the tangent are unavoidable they should be placed, both for appearance and utility, at the summit between two grades. It is of the greatest disadvantage to break a tangent at a depression

A Curve on Main Line

formed by two grades of different inclination. Many men do not fully appreciate that in making a general correction of the line, either on tangents or curves, the best results are obtained by the foreman when he stands erect, as the effect of the correction through a longer distance can then be observed more readily.

Lining Curves.—When curves are to be lined it is best to do this work by the string method. If the foreman has not learned the complete method he can at least help by taking the ordinates, doing so in a careful manner. They are measured at stations previously marked on the rail whose distances apart are one-half the length of the string. The stations are numbered in order and extend as far as there is the least curvature. The mistake should not be made by the foreman of failing to overlap the chords, and the ordinate should be measured correctly at every point that has been marked.

Lining Done Gradually.—When the solution has determined the proper throwing of the curve, the foreman will line the track. He should be careful to do this gradually, so that a train passing over the track being lined may not be made to swerve too quickly. A very bad condition of this kind might cause a derailment. This is especially true when the weather is hot and the rails are tight, for the track will be loosened by the throwing, and will therefore buckle more readily. If the throwing is outward and is done carefully, the tendency to buckle will be reduced. When the throwing is inward and is considerable, it may be necessary first to substitute for a full rail on each side one that is several inches shorter. The foreman should always watch the throwing, so that a short kink will not be left in the line when a train is approaching.

Gaging Track.—An essential part of the completed repair of the line and surface is the correction of the gage. The need for this adjustment will be seen more readily when the line and surface have been made correct. This work must generally be done by gangs working in twos or threes. It is impossible for the foreman to watch the work of such gangs, and they should feel a direct responsibility for the safe performance of the work. No more spikes should be withdrawn than are necessary, and the approach of trains should be watched for, so that full spiking shall always be provided. Care should be taken in spike lining that the gage is widened rather than tightened; but this should never cause the gage to become wider than 4 ft. 9¼ in., and it should not be made less than 4 ft. 8¼ in.

Attendance of Signal Forces.—When any work is done on bonded track which will interfere with circuits or with interlocking or signal appliances, the signal maintainer should first be notified. An interlocked switch should neither be lined nor surfaced unless the maintainer is present. Even when lining is done at signals he should be on hand, for there are certain clearances to be maintained at such points for which he is responsible. While working on bonded track such care must be exercised in the handling of material and tools as to avoid making a metallic circuit between the rails. This error is most frequent from bars being allowed to fall across the two rails. A steel tape lying across the track may shunt the track circuit; a rail or a switch laid across the rails will be certain to do it. This error not only delays traffic by putting the signals in the stop position, but might cause an accident through a severe application of the brakes being made by the engineman to avoid passing a signal in the stop position.

Eliminating Joints From Road Crossings.—Too much emphasis cannot be laid upon the importance of eliminating joints from road crossings by the use of long rails. It is well known that the joints at such places are by far the most troublesome to maintain. It is of further advantage to clean the ballast at road crossings before the advent of freezing weather. Most of the shimming that is required in the winter may thus be avoided. The foreman can save himself much labor in renewing burned ties if he is alert to notice ash pans that drop burning coals. If report is made of the engine number, prompt correction of the defective ash pans can be made. The three essentials in reducing maintenance are good drainage, good ties, and good judgment in organizing the work of lining and surfacing.

54. Track Maintenance on Branch Lines

Points of Difference.—In the preceding article the maintenance rules were stated which govern surfacing, lining and gaging in general, and these were developed specially as concerns the main line. The modifications necessary to adapt them to branch lines, as well as the additional points involved, will be discussed in this article. The refinements which are

imperative in main line repairs are generally out of the question on the less important branches. In the case of the latter the speed is restricted for both passenger and freight trains, and the track structure is therefore of a lower class. Smaller gangs are assigned to the repairs and these are usually for that reason of lower efficiency. As a rule the tangents are shorter and the curves sharper and more numerous. While the freight traffic may be just as heavy as on main line, it is moved at a slower rate of speed.

Maintenance Features Compared.—On a main line the principal item of work is surfacing; on branch line the three items of roadway cleaning, applying track material and surfacing are of more nearly equal scope, and on both they compose over nine-tenths of all maintenance work. The following table of costs per year per mile of all tracks on a double-track main line and a single-track branch line, with average physical characteristics, illustrate the divergence. The figures are for 1915 and probably as concerns the items of cost should be trebled for 1921. It is well to remember also that surfacing in cinder is less than one-half as costly as in stone for equivalent distances.

	Main Line		Branch Line	
Feature	Cost	Per cent	Cost	Per cent
Roadway mainteance	$180	20	$215	33
Applying track material.....	240	25	180	25
Surfacing, lining, gaging.....	450	50	215	33
Other M. W. & S. (Excl. Superintendence)	70	5	55	9
Total M. W. & S.....	$940	100	$665	100

It is interesting to note that the costs of applying material plus surfacing costs are in the same ratio for the two classes of road as the speeds prescribed are to each other, namely, as 70 is to 40. The items of surfacing, lining and shimming only will be considered in this article, as gaging on branch lines is an element for safety rather than track maintenance as the term is here used.

Surfacing in General.—While the item of surfacing includes track raising, the cost of this work, where the road is raised out of face once in three years, is no more than one-tenth of

the total, and it may therefore be neglected. In a general sense surfacing comprehends the raising of low joints, the correction of irregularities of the level, and particularly the detailed adjustment of superelevation, both of the curve proper and of the run-off. This last item vitally concerns the safety of the movement, since the run-off, by reason of the limitations established by the alinement, is generally made at a rate but little above the safe figure. As cinder ballast is typical of branch lines generally, the points suggested will apply mainly to that kind of roadbed, although, as is well known, there is little difference in the detailed methods of tamping in cinder, gravel, chats and chert ballast where tamping by the pick or bar is employed. This means of surfacing should always be used, unless the traffic is light, when the tamping may be done with the shovel. As was stated previously, the hard tamping extends from the ends of the ties to 15 in. inside the rails, the remaining space in all cases being loosely tamped with the blade of the shovel.

Detailed Method of Surfacing.—Preliminary to detailed surfacing, it is necessary to drain the water from the track if is being held, and this should be done if possible a day or two in advance of the surfacing, to allow the roadbed at the wet place to dry out thoroughly. The next work is to tighten the bolts and drive down the spikes so that the tie may adhere closely to the rail when the low spot is raised. Only enough ballast should be removed from about the tie to enable the pick or bar to tamp well beneath it. The low places on one rail should first be surfaced up to a good grade with the eye, and proper cross level then obtained for the two rails by means of the track level, previously tested and adjusted to insure accuracy. At first the tamping is only of the outside until several trains preferably have passed over the track. This is desirable in order to settle the ties to a uniform bed and thus disclose any weak places in the first tamping. After these are corrected the spaces inside the rails should be tamped solidly, and finally the middle tamped loosely with the shovel. In the case of heavy tonnage movement a cross tamping well may be given, assuring a firm bed throughout the tamping areas of the track. The roadbed should then be filled in to ½ in. below the top of the ties, the shoulders

dressed off neatly, and the ballast border trimmed to a regular line.

Degree of Maintenance.—On branch lines it is not necessary to level up the track over a considerable distance when the difference between the two rails on a tangent does not exceed ½ in. This condition may properly be allowed to continue until such time as the track would ordinarily be surfaced out of face. The best practice, however, requires that on branch lines, as well as on main lines, a uniform superelevation of curves should be preserved as far as practicable. In the case of the run-off it is never permissible to vary from the established superelevation, where the error is known, as there is danger of the side bearings of cars becoming fouled, if further error should develop. In fact, safety of movement requires that the superelevation of curves, and especially of the run-off, shall be tested frequently with the track level and the eye, and be maintained faithfully.

Importance of Lining.—The lining on branch lines is apt to be neglected because the force is not sufficient to do the work efficiently, if at all. This may be overcome by combining adjacent section forces specially for this work. Long tangents are usually thrown between summits, and the shorter ones with a due consideration of the effect upon the adjoining curves. The detailed subject of lining curves is a large enough question to constitute a treatise of itself. As regards lining of track in general it is required that a piece of track which has been surfaced over shall be lined without fail before the day's work is closed. Since it is not always possible to back-fill track which has been surfaced or raised, an indifferent line is liable to deteriorate further and become a source of danger. A track in proper line is also less likely to buckle, because the stresses then are exerted in a direct line. It is well to give special attention to the line at the ends of bridges, at road crossings and at station platforms.

Practice in Lining Track.—It is usual on the Pennsylvania to regard the outer rails away from the center line as the "line" rails. There is a definite advantage in always maintaining the line of a certain one of the rails by throwing, while that of the other is maintained by attention to the gage, as thus a minimum of disturbance of the track is

assured. It is especially important on branches that due care be used to determine the general correction required in the relining. The foreman should study the line from as great a distance as he can well see, and from a height if this is possible, but certainly while standing erect. The worst swings may thus be taken out first, and then a detailed lining be given while he is within about 100 ft. of the men. It is necessary that the men be equally divided on the two rails, and that the man leading in the operation shall be near the center of the group. It is also of prime importance that the middle point of the irregularity shall be indicated for the concentrated throwing. Care in the choosing of this point is the gage of a foreman's efficiency in lining track in any character of road, but especially in the more lightly held cinder ballasted branch line.

Shimming Track.—The maintenance of branches in winter almost always requires some shimming of the track to compensate for the effect of frost. This work should be kept to the minimum required for safety. The shims employed should preferably be of oak and made in the shop of different thicknesses to suit varying conditions. It is desirable for shimming above one inch, that the shims be of a standard design, at least 18 in. long, and bored to suit the sections of rail in use. The 5½-in. spike is ordinarily adequate for use with shims up to 1 in. thick, but for greater thickness a special spike is required. It is believed that no greater shim than 2 in. should ever be employed on the top of the ties; if the depression exceeds this, a slow order becomes imperative. Shims require faithful attention on the part of the foreman and track walkers to change them as becomes necessary, and to remove them promptly upon the occurrence of a thaw, or at the close of winter. A detailed surfacing at such points is first in order in every case.

55. Maintenance Through Track Tanks

The Track Tank a Feature of Eastern Roads.—It is recognized that only a limited number of railroads have adopted the track tank for supplying water to locomotives in transit, and that these are located mainly in the eastern section of the United States. The number, however, includes three of the largest systems in this country and several others having

a considerable mileage. It is believed, therefore, that the subject of track maintenance at such places will be of more than passing interest, and that the points given for beautifying the surroundings will also convey useful suggestions.

The track tank is felt to be a necessity in certain congested districts. The competition for passenger business is so keen and the demand for quick transit so insistent, that it would be entirely out of the question to introduce into the schedule of fast trains running between metropolitan cities a stop of even a few minutes for water. There is indeed a growing tendency to scoop water without slackening speed, and it is rather the rule for trains to continue at normal speed over water troughs. While a considerable amount of water is wasted through this practice and there is present the danger of ultimately weakening the roadbed structure, the first is justified and the second may be met by a special protection.

Essential Provisions at Track Tanks.—A photograph shows the paving and certain other features at a water station on

Paving at Track Tanks

the Pennsylvania. The main elements in a typical station are the transverse pipes for drainage, the paving of the shoulders and center ditches, and the heating system for thawing ice. The importance of the first is manifest; the

desirability of the second as a labor-saving method and a device for safety is becoming better appreciated; and the value of the last as a protection to the traffic as well as an alternative for hand labor, has been demonstrated by an experience of several winters. The plant shown in the photograph has tanks 29 in. wide and 1600 ft. long; but many pans are only 19 in. wide, and a length of 1200 ft. usually suffices where double heading is infrequent.

The Cross-Drains.—The fact alone of the shoulder being paved requires that some means shall be provided for passing the water to the sides. This has been accomplished most efficiently by the use of 12-ft. lengths of 6-in. cast iron pipe inserted at intervals of 300 ft. on each side and so staggered that a drain occurs every 150 ft. The primary requirement to render the drains effective is a clean bed of ballast in the center ditches. If this is afforded at the time the paving is laid the need is met for all time, since no material tending to clog the ballast will find entrance through the paving. When the subgrade is of a kind that puddles readily, a deep bed of ballast is required; and it is also desirable in some cases that this shall be cushioned further with a bed of ash-pan cinders. At one location the cinders are replaced by a 15-in. deep bed of 6-in. cobbles, carefully laid to a uniform cross-section.

At three important water stations the transverse pipes are omitted. It is considered that the subdrainage at one is taken care of by the fact that there is an 18-in. bed of ballast overlying a 24-in. cushion of cinders; at another, by 4 ft. of ballast. There is at each of these stations a longitudinal concrete drain, so graded as to cause the water to flow to outlets entering the cross tunnels, which are spaced 230 ft. apart. At the station illustrated in the photograph the drainage is aided by perforations in the steam-pipe boxes, through which the water runs and is given an outlet at the end of the boxes. It has been found, however, that greater facility in maintaining surface is obtained at points where transverse pipes are provided to afford prompt passage of the water to the sides.

The Paving.—The preferred type of paving is that shown in the photograph in which the long dimension of the stones,

both in the shoulders and center-ditches is laid parallel with the track. The particular advantage of this method is that practically no half paving blocks are needed to break joints, which is the case at every other row, when the stones are laid transversely. At most places the center-ditch is not hollowed, but is paved with a straight grade flush with the top of the tie. This tends to throw the water at once to the sides, and realizes the benefit of the 3-in. higher grade of the inner tracks.

The shoulders are paved at all points, generally to the standard roadway section, the top of the stones just touching a straight edge laid from a 5-ft. 3-in. line to the top of the ties. The ditch is, however, given 1 in. more slope than that specified by the standard. Eight lines of paving blocks thus compose both the ditch and the shoulder. In the use of this method of paving a margin of about 1 in. is provided for lining the track. Within the ditches on the side of the tie that is not lined an average is struck and long ties are first cut off, a 2-in. excess being generally sufficient to require such cutting. A 1-in. board is then placed along the ends of the ties on each side of the center ditch and the paving confined to the lines thus established.

Care is taken that the stones are laid on a clean ballast bed, and that this is not first smoothed up with any material that would interfere with the drainage. The paving of the shoulders on the leaving end is extended about 400 ft. beyond the troughs and within the intertrack space about half that distance. The work of laying the paving can be done with ordinary labor directed by a capable foreman. Second-hand blocks are easily obtained in any of the larger cities at a merely nominal cost. An excess quantity should be purchased so that the stones may be selected of a fairly uniform size. After the paving is completed the work will require a general ramming, and the surface can then be made regular throughout.

Thawing the Ice.—The trouble from ice forming along water troughs, and particularly at the ends, is a serious one. In severe weather this condition creates a positive menace to the safety of the movement. A method of thawing the ice by the use of heating pipes carrying live steam has given

good results at several important water stations. This system consists of a double line of 2-in. pipe, the portion throughout the extent of the troughs being just outside the rails, and that beyond the leaving end about 12 in. within the rails. The protection is carried 600 ft. from the end of the troughs. This scheme, aside from the increased security obtained, effects a large saving in labor. Of still greater importance, it furnishes protection against a dangerous condition developing during the night when it might be overlooked.

Beautifying Water Stations.—There is so little labor involved in maintaining lawns and shrubbery along track tanks, and the appearance is so easily made attractive, that all roads can afford to beautify at such places. Besides grass which is everywhere suitable, certain shrubs set out in a natural way are very pleasing. At the least, the buildings, which are not always sightly, should be screened as far as possible by clumps of shrubbery. Willows are especially appropriate for a hedge along the right-of-way lines, and they are certain to thrive at such locations.

The walks which lead along the extent of the troughs, or which cross to the several features of the layout, should be well maintained with screenings or other suitable surfacing material. They are made more attractive if bordered by a low privet hedge. The water tanks, whether of wood or steel, and the standpipes or water bridges connected with the system, require periodical painting for their preservation, and this should be of a color which will harmonize with the surroundings. The slopes of the embankment carrying the railroad (the track tank being rarely located in a cut) should be sodded or covered with honeysuckle or other hardy vines. The right-of-way at troughs should be policed carefully at all times.

56. Track Maintenance in Tunnels and Over Long Bridges

(a) In Tunnels

Close Joints Essential.—The greatest deficiency in all the older tunnels and in many modern ones is a lack of provision for drainage. This defect complicates the maintenance of tracks in these tunnels to this day, and will continue to do so as long as the standard track construction is employed.

Indifferent line and surface are therefore unavoidable with the ordinary track structure, and these in turn cause rapid deterioration of the rail, in an even greater degree than does the corrosion from gases in steam-operated tunnels. For this reason it is important that rails in tunnels be laid with close joints, and that a minimum opening be maintained through an ample use of rail anti-creepers.

Preserving Clearances.—In the absence of a permanent lighting system, the surfacing must be done with torches, and great care is necessary to obtain even passable results. The tamping is invariably performed by hand, since the noise made by the tamping machine precludes its use in tunnels. The lining and surfacing of tracks must always be done with due consideration for clearances, both lateral and overhead. It is therefore necessary that the grade and alinement shall be indicated by permanent reference marks. At one location copper bolts are set in benches cut into the side walls of the tunnel. While it would have been handier if these points had been established at a constant height above the top of rail and a uniform distance from the gage line, this was not practicable, and the dimensions vary at every point. Blue prints on file in the tool house and in the supervisor's office give the required data for the several points, which are spaced exactly 25 ft. apart, throughout the length of the tunnel.

Renewals Made at Night.—The general line and surface in tunnels can be handled most comprehensively when renewals are being made. This work is almost always done at night when trains movements are fewest, and then with absolute use of tracks for the period of renewal, trains being diverted to another track during the operation. Repairs are made out of face as regards rail, ties, ballast, and line and surface. All stripping of the old ballast and delivery of material are completed before the track is taken over, and similarly the back-filling and loading of the old material are done before the track is returned to service. A large force of men is required for the work, and the best artificial light obtainable is needed to facilitate the renewal to the utmost possible extent. In the detailed lining and surfacing through most tunnels, the aim is mainly to avoid low joints and swings between the established points.

Need for Ventilation.—The cooling and ventilation of tunnels are matters of importance, both to the train passenger and the trackmen. Steam locomotives generate heat, gas and aqueous vapors, the first two of these being also produced by the lights necessary for working in tunnels. Where trains are few the lights may indeed constitute the larger source of contamination. The gases from the locomotive are carbon dioxide and monoxide, nitrogen and sulphur fumes, all of these in excessive quantities being detrimental to health. When the temperature is above 90 deg. there is discomfort to the train passenger, and when it rises above 100 deg., with a high percentage of humidity, difficulty will be experienced by men working in the tunnel. It is thus imperative that the emission of smoke by locomotives passing through tunnels shall be restricted through careful attention to firing. It is also necessary that the foul and heated air shall be removed as quickly as possible. The maintenance department has control only of the kind of lights employed and the degree of care in their use. The mechanical department must be depended upon to provide a proper means of ventilation. A natural ventilation in tunnels exists only in theory. Doubtless it is, as has been claimed, of advantage in the ventilation of tunnels to locate them on tangents; but this is seldom practicable and, in the case of the longer tunnels, does not obviate the need for artificial cooling and ventilation.

Means of Ventilation.—The essential provision for ventilation is a fan at the portals and at specially provided shafts, to force in a large quantity of fresh air at low pressure. These are required at close enough intervals to prevent the new air becoming heated before it can reach remote parts of the tunnel. Power driven blowers are also necessary to cause withdrawal of the vitiated air. The lights used by the track forces should be of acetylene rather than oil, because the latter makes twice as much heat as the former and 50 per cent more noxious gas. Uncleanliness of the men's bodies is no small factor in producing air that is prejudicial to health. Satisfactory results in maintenance within tunnels can only be had when every possible means is employed to provide a pure and fairly cool atmosphere.

Rules for Safety.—The rules specify that men working in

tunnels shall be provided with a sufficient number of lights, never less than two, and that they shall, upon the approach of a train, take refuge in the manholes. The first is required in order that the engineman may be aware of the presence of the men in time to sound a warning if necessary. The second implies that a lookout will be maintained so that sufficient time will always be afforded for the men to reach shelter. The manholes in the tunnels under an eastern city are spaced 150 ft. apart on both sides, and staggered so that there is a refuge every 75 ft. Unless men are working with use of tracks, it is required that they shall be in the manholes while a train is passing on either track.

Precaution by Engine Crew.—The greatest danger from movements obtains when trains are run through the tunnel against the current of traffic. This occurrence should always be attended by a constant ringing of the engine bell, with a sharp lookout from the locomotive for men working on the track. Failure to observe safety rules should be unfailingly reported. While it is preferable that inexperienced men should not be employed in track work in tunnels, this is sometimes unavoidable, and they should then be kept close to the foreman and be individually safeguarded. They should specially be instructed that if unable to reach a manhole escape may be had by lying prone upon the roadbed in the center between the tracks.

Watchmen Essential.—It is prescribed that a watchman shall always be employed to warn the men of the approach of a train by the blowing of a shrill whistle. He should have at hand a red flag or lamp which could be used to stop a train in case an answer to his signal is not returned. When work is being done with provisional, and not absolute, use of track, special care is necessary, because the traffic might be turned back upon the track being worked on without notice. Work in a tunnel should invariably be suspended when the fans and blowers go out of service. Heat and gas exhaustion in such cases are difficult to combat. The repairs well may be discontinued during the periods when the traffic is so dense as to overtax the fans. In some tunnels the movement is stopped when the fans go out of commission and it is not resumed until they are restored to service.

(b) Over Long Bridges

Depth of Ballast.—The author had experience in maintaining the two tracks of a high speed main line over two concrete deck bridges 1 mile and 0.5 mile in length, respectively. The tracks were ballasted with ¾-in. stone laid 8 in. deep below the bottom of the tie. The essential reason for the use of the small size of ballast was the need of frequent raising of the track to avoid a center-bound condition. The lifts had to be made as light as possibly could be tamped, so that the depth of ballast might not increase eventually to an extent inviting heaving.

Practical Depth of Ballast.—There is a very definite limit

Solid Ballasted Deck Trestle

to the practical thickness of the ballast cushion in such roadbeds. Experience has shown that between 12 in. and 18 in. is the most unfavorable depth, a greater depth than

18 in. being generally out of the question because of the excessive load that would be imposed upon the structure. It is necessary, therefore, to keep the depth of ballast bed less than 12 in. beneath the ties unless the structure has been designed for a high dead load, when more than 18 in. is permissible, as much as 24 in. being used in several recent installations.

Increased Maintenance.—The inadequate lift that was permissible at each surfacing over the bridges in question resulted in a more or less center-bound condition of the track at all times. This necessitated a greater frequency in tamping the track and required the use of the most expensive process, the spotting of low joints. As is quite well known, the line also is more difficult to maintain in a center-bound track, and thus, there unquestionably is increased maintenance of the tracks over solid floor bridges. Careful tests have shown that this increase is one-fourth above the cost of similar track on the ground. The cost of maintenance of line and surface in such tracks at present wages would average $1,500 per mile of single track per year.

Longer Ties at Ends of Bridges.—The ends of bridges are a source of anxiety in operation as well as an increase in maintenance expense. The track settles at all times and requires close watching and faithful attention to surfacing. Maintenance has been reduced in several instances by the use of longer ties at both the approach and leaving ends of the bridges. Such ties are 10 ft. 6 in. long at the back-walls and diminish regularly from the bridge through the adjacent 10 ft. of track to the standard cross-tie length. When surfacing is being done at the ends of bridges, it is proper to raise the track higher than the true grade to allow for settlement that is certain to result. With some kinds of roadbed a superelevation of 2 in. is not excessive. Especial care is necessary to maintain good line at the approaches to a bridge. The line over the longer open deck bridges, through varied effect of sun and weather, can only be maintained correctly by persistent spike lining.

Anchoring Rails.—There is a serious problem presented in the safe maintenance of tracks upon long open floor bridges, especially where they are accompanied by the presence of a drawbridge. The rails are subject to creeping in an extreme

degree, and they must be held upon the draw particularly. The generous use of holding devices on the approach, and their application upon every tie throughout the draw, is the only practical solution. Even then it is frequently necessary to cut other rails, and this is required periodically in all cases with the changing of the seasons. Creeping trouble is accentuated by the necessary use of tie plates on all bridge ties, and the unfavorable strain brought upon the bridge structure through the anchoring of the track must be accepted and if necessary provided for. Watching the tracks at such points is one of the strictest needs of maintenance.

Battered Ends.—It is of the greatest disadvantage to allow the rails in track over a bridge to become battered at the ends as the impacts thus created cause definite injury to the bridge structure, besides being a source of anxiety to the passenger. The rails at the ends of drawbridges should always be mitred and be reinforced with a lock designed to bridge the joint. The use of a speed in excess of 30 miles per hour over drawbridges is not regarded with favor on most roads and a speed in excess of 50 miles per hour is not considered proper over any steel viaduct or long pin-connected bridge.

Watching Fires.—The matter of watching the deck of the longer bridges usually is important enough to require the service of regularly assigned bridge watchmen. The principal duty of these men is to follow trains to see that fire does not take hold upon the wooden part of the structure. Water barrels are maintained at regular intervals across the bridges, and observations are made to see that there is water in them and that it is protected against freezing in winter by the addition of salt. On account of the damage resulting to the steel work from the brine being blown out of the barrels by high winds, care should be taken to keep the barrels covered. A distinctive style of bucket made from boards should be kept in each barrel ready for immediate use.

Cleaning Bridges.—The cleaning of all dirt from the bridge seats and superstructure is an imperative duty, and on the Pennsylvania this work is required to be done on the last working day of every month. Where the steel is subject to the occurrence of dirt that is difficult to reach, as within open columns, or to constantly recurring moisture, such places are

permanently protected by the addition of asphalt or concrete. The maintenance forces should be required to keep grass and weeds from growing up about wooden structures, because their presence invites decay and when dry they introduce a potent fire hazard.

Steel Guard Rails.—The utility of steel guard rails over long bridges is well recognized and few bridges of any length are now without this protection. It is necessary for full service that the guard rails on the curved approaches be equipped with a rail brace on every tie and on the straight portion over the bridge on every other tie, these being on a different tie for each of the guard rails. All joints in guard rails are applied with full bolting and the guard rails are spiked at every tie. It is required that the height of the guard rail shall not be greater, nor more than ½ in. less, than that of the main rail in any case. The rails used for guard rails should be only such as are unfit for relaying, but care should be taken to lay them with the better side next to the track rail.

CHAPTER XV

MAINTENANCE OF YARDS AND TERMINALS

57. Organization for Repair.

Lower Degree of Maintenance.—Maintenance rules require simply that yards shall be maintained in serviceable condition. It is universally recognized that the character of repairs, both in the renewals and in surfacing, is greatly inferior to main line standards. There is no need for a high class of track for yard movement, which seldom exceeds 20 miles per hour, and in any case the kind of material available and the opportunities for working over the tracks preclude effort toward fine results. The main object to be attained is the safe passage of traffic and the avoidance of interference with operation while the renewals are being made. There are certain obvious rules for yard maintenance which only need to be stated to be recognized as standard practice. A definite program of work is out of the question, because frequently, when the business of the yard is slack, material is not available, and when material is plentiful, the use of tracks may be difficult to obtain. There is no branch of maintenance where a sliding program is so unavoidable as in yard work.

Typical Gravity Yard.—The important question of organization will be rendered more simple if referred to a concrete example. A certain terminal yard serving three important divisions in the eastern territory is typical of large yards generally. The yard contains 50 miles of track and 225 switch connections. It has two main tracks through the center for northward and southward movement of through trains and 11 receiving tracks for the traffic in each direction, these converging over humps and leading into two classification yards of 22 tracks each. There are four advance tracks in both directions which relieve the yard of trains as fast as they are made up. An extensive engine yard is tributary to the main layout where the daily movement of engines in and out is

close to 200. A considerable shop yard at this point is maintained by a separate organization.

The Forces for Maintenance.—The yard is under the direction of a general foreman and has three subsidiary units known as north end, south end and engine yard forces. A special crew of 8 picked men, assigned to the charge of an assistant foreman attached to the office of the general foreman, is kept available for immediate response in emergencies. The north end and south end forces number in normal season 16 men each, and the engine yard force has 12 men. Current repairs, such as rail and tie renewals, surfacing and policing, are directly the business of the several forces in their respective sections. Incidental repairs, which include replacement of broken rails, renewal of switches and frogs, adjustment of guard rails, butting rails to close open joints, etc., are the duty of the smaller force and extend throughout the entire yard. The utility force has the assistance of the several units in their territory when required. The use of a small force for the occasional items of light repair, which usually require special provision to be made for the work by the yard operatives, avoids much of the lost motion which obtains when a larger force is employed, since there is sure to be some delay in getting the use of tracks and in moving the material and tools required for the work.

58. Storage and Distribution of Materials.

Storing at Humps and at Head of Ladders.—The most important item in yard maintenance is the provision and distribution of material for repairs. This is almost wholly confined to ties and switch timber, since general renewals of rail are seldom made. The character of operation renders the 70-lb. rail of 30 or 35 years ago still serviceable where properly maintained. The ties are received on cars and must be unloaded and piled neatly where opportunity will be afforded for loading them onto hand trucks. This will usually be at the head of the several ladders. In the case of hump yards, the vacant spaces where the tracks converge supply excellent storage ground. They are in fact the most favorable locations in the yard, since they have access to either receiving or classification yard. Also in the distribution of the ties the movement

of the hand truck is under the eye of both the yard director and the sub-foreman while arrangements are being made for the use of the track. Thus, the moment the use is given the truck can be passed into the appropriate track, while the movement of cars or hump engines is suspended for the purpose. A limited supply of material at the opposite ends of the several yards is a convenient stock for such times as the use of a track throughout cannot be had. It is always desirable to distribute the switch ties close to the point where they are to be applied so as to permit of the several ties being carried readily to their places by the men or at least taken there on pony trucks. The emergency materials, such as frogs, switches, repair rails, etc., will be located after careful consideration of facility in trucking them to points where their use may be required quickly.

Utility of Work Train.—While renewals are being prosecuted actively a work train will be indispensable. By no other means can the flow of material be maintained or the necessary policing performed. When a track is taken over, it is a duty along with the renewals to gather up all scrap and rough material found throughout the track, which for safety has been placed either in the track or upon the ends of the ties. Opportunity will also be had for loading the accumulation of coal and other lading spilled from cars at various points within the tracks. Ballast will have to be dumped as required, and the old ties piled from day to day will need to be taken away promptly. The delivery of the ties to the several tracks will generally be made by means of hand trucks. The pony truck should be used wherever possible for single items of material such as a switch point, a rail or a limited number of ties, and the hand truck should only be used when the pony truck will not answer the purpose.

59. Use of Tracks.

Classification, Receiving and Advance Yards. The renewals in a yard can not practically be made without definite use of tracks. In the case of classification yards this is necessary to prevent injury to the men from cars being run onto the tracks, and to assure that departure with the old ties at the end of the day will not be obstructed. It is desirable, both as a

safety measure and in order to conserve the full use of the track, to spike the switches at either end. In the case of the receiving yards a special practice will avoid all interference. A thoroughfare track is always maintained through these yards for the return of the hump engines. While renewals are in progress in these yards, the track being renewed can be made the thoroughfare track temporarily and the regularly assigned track be used for receiving and storing of trains. This plan of renewal may be pursued throughout the entire course of the renewals in the receiving yards, and thus no track be unnecessarily obstructed. The renewals in the advance tracks will be made somewhat on the lines of a compromise between these two schemes.

Alternative Program.—The use of tracks will be arranged for by the yard master upon notice the day before. In the case of the classification yards it will be necessary to clear cars from the desired track and generally plan for a split classification while the track is being used. In the case of the receiving yards, besides clearing of cars from the desired track, proper notice will have to be given the switchman as regards the operating details. Since yard people are only human the matter of providing for the surrender of a track may be overlooked, or it may prove impracticable at the last moment to give up the track. It will be well for the foreman always to have an alternative proposition in mind. A track requiring repairs may be at the moment ready to turn over in place of the one desired. If the ties are spotted ahead for several different tracks no time will be wasted in changing to another track. Most of the time lost in making renewals in yards is caused by men waiting upon the use of tracks. If this detail is disposed of promptly a long stride will be made toward overcoming one of the handicaps to efficiency.

Co-operation Essential.—The use requested should be definite and the surrender made at the time prescribed. On the other hand, the yard master should not expect surrender of the track in advance of the time fixed. Expeditious renewal requires co-operation between the yard and track forces. The repairs have to be made, and the yard people well may make some sacrifice to attain that end. Similarly the yard people can help greatly by arranging promptly for movement of the

hand truck about the yard. The clearing of a track to close an open joint, or to renew or turn a defective rail, or to pick up spilled lading, directly concerns operation, and the yard masters will, for their own advantage, afford the necessary facilities for the work. The repair gangs, on their part, will be prompt to use and surrender the facilities granted. They will also not fail to give every protection necessary for doing their work safely.

60. Application of Ties and Other Materials.

Digging in of Ties.—Labor has deteriorated to an extent which precludes the renewal of ties by the older methods. Formerly the raising of the track and a mere digging down of the bed sufficed for the application of the new ties with the work of the shovel reduced to a minimum. Nowadays such practice would result in distorting the surface to the point of danger. The experienced labor is gone and that now available is slow to learn, partly by reason of being unintelligent, but mainly because of unwillingness. With such labor, lifting of the track with the jack is sure to result in some one pushing ballast under the track, or causing it to run there, and thus a high spot will be introduced. Digging the ties in, with the track surface undisturbed, seems to be the better practice with present labor. If there is a good bed of ballast this is not expensive of labor, and if care is taken to tamp the ties thoroughly, no disadvantage will result from the use of the method. In the renewals in yards attention should be given to the kind of ties to be used bearing in mind that generally yard ties will rot out before they wear out. For this reason, treated timber or chestnut, when they are available, should be used as far as possible. **The most essential element in yard renewals is that complete repairs should be made and no single spot overlooked that may later become a source of accident.**

Surfacing After Renewals.—It is especially important that a proper tamping be given in order to avoid the possibility of broken rails resulting from a loose condition of the new ties. The placing of the ties is simply rough labor, and the lining and spiking up of the ties can also be done by inexperienced men. In connection with the renewals it is desirable to drive down all spikes in adjacent ties. This will facilitate the sur-

facing which follows as closely upon the renewal as may be practicable. It should be regarded as a duty to remove from the yard at night all old ties renewed and any new ties not applied. Thus, serious accident to yard employees will be avoided. In the event an emergency should make this impossible an appropriate notice should be posted so that the men can protect themselves accordingly.

Renewal of Switch Ties.—The renewal of switch ties should proceed on exactly the same lines as in a main track. The ladder is constantly in use and renewals must be made between the movements. The ties are nearly always renewed by the method of spotting, since it is highly undesirable that the ties in a ladder switch shall be in an entire state of decay at one time. By applying only a portion of the timbers, the surface, line or gage is not perceptibly altered, and the question of safety is not so directly affected. The ties should be marked only after careful testing with the pick, and the position of each tie and its length should be indicated upon the rail. The ties for the renewals should be brought near to hand and the defective ties replaced one by one. Care should be taken to provide full spiking the moment a new tie is applied and the new ties should be tamped solidly before the day's work is concluded. Not infrequently switch ties are renewed because of defective ends. These should be cut off, and the tie, if otherwise sound, be used again. Economy in yard renewals is required, not only by reason of economic practice in general, but because of the difficulty of making the renewals.

Renewal of Frogs and Switches.—The replacement of frogs and switches in a yard presents a serious question for solution. Manifestly it is not proper to make renewal until the members have attained the ultimate limit of safe wear. No arbitrary standards have yet been agreed upon for the determination of this matter. The judgment of the foreman, matured by careful observation and study of past derailments, will be the deciding factor. The development of M. W. reclaiming plants, which generally are located close to the larger yards, has simplified the matter considerably. Repair material is thus made available immediately, and there is not the necessity of continuing switch members in the track beyond the time of safe use. It is well recognized that blunt switch points in com-

bination with worn flanges of wheels produce derailments, and that a frog with the point worn more than ½ in. below the original plane of the top has reached a critical stage. The guard-rail gage, which is a fixed dimension measuring 4 ft. 6¾ in. between gage line of frog and flange side of guard rail, (whatever the gage of the track), should be faithfully preserved. The line through the lead, and the line and surface back of the frog, are features that demand faithful maintenance. Proper adjustment of the ground connections is an essential item in yard maintenance. Full section stock rails at switches increase the life of the points and go a long way toward preventing lack of adjustment in the fit of the point.

Use of Track Accessories.—Economy in the use of items less essential to the track structure, which may be called track accessories, is especially important in yards. Tie plates are necessary on sharp curves, but are seldom justified on tangents in yards. The tie rod is a most useful accessory at turnouts, but it can be used extravagantly. Five rods is as many as can be placed effectively on the curve of the turnout between switch and frog. Care is necessary in applying tie rods, as an inexperienced laborer can so tighten the gage that an unsafe condition will be produced. A track gage should always be placed while the rod is being drawn up to the rail. Rail anti-creepers are useful for holding the two lines of rails ending at the switch point, which are free to move back and thus tighten both the track and guard rail gage; but they are hardly justified in yards at other places, except for special uses. Tie spacers are useful at the head blocks of switches to maintain the switch stands in good adjustment. Obsolete materials, such as tie plates of older and lighter pattern, rail braces, etc., may be used in yards where they will render service regardless of fixed rules.

61. Lining and Surfacing.

Surfacing with Use of Track.—Unless the general tie renewals are urgent it is desirable to obtain the use of the same track on several successive days, so that the tie replacement may be followed by a general surfacing and regaging of the track. This work cannot be done in the usual manner over inferior rail, with raising frequently much greater than in ordi-

nary maintenance. The light rail with which most yards are laid is usually more or less surface bent. It is therefore not practicable to raise the centers in rotation with the joints. The best results will be had by raising the joint ahead before the center back of it is raised. Some care will be required to see that the men do not tamp ties remote from the joints which will come up when the center is raised later. The track will finally be brought to a fair level with the use of a correct level board. In this surfacing it is desirable again to drive down any spikes that may not be tight to the rail.

Gaging after Lining.—The line will be made as good as required, and then observation of the other rail will show where regaging is necessary. If a yard track has no less than 4 ft. 8¼ in. gage or no greater gage than 4 ft. 9 in., regaging will not be necessary. Places will be found where the gage is as little as 4 ft. 7½ in. and as great as 4 ft. 11½ in., and these represent the extremes of what will just pass the equipment. Of course the figures first given represent the limits that may be regarded as passable, and a little variation from these suffices to make an unsafe condition. Wide gage and bad line will generally be found on the curves back of the switch ties, where care is not taken to preserve an approximate centering of joints. This is a small detail, neglect of which frequently leads to a condition inviting derailment. The staggering of joints on curves is especially necessary to avoid the "kinks" and "elbows" which develop in yard alinement. When this advantage is lacking it is proper to relay the rails to restore the standard condition.

Surfacing Under Traffic.—Tracks may be surfaced under traffic if assurance is had that a train will not be run upon the track and be stored for an indefinite time. When surfacing is being done upon a thoroughfare track it should be with an understanding duly arrived at with the yard master. In the event it becomes necessary to use the track for storage, prompt notice will then be given so that the repairs may be brought to an end and the surfacing gang diverted to some other track. The surfacing about ladders and that in the advance yards can usually be done in the manner in which this work is conducted on main line. Special care will be necessary to insure that the lifts are made gradually and no change

in relative superelevation greater than 1½ in. in 33 ft. introduced at any point while service is permitted. The switch stand connections will have to be watched to see that they do not get out of adjustment by reason of such . surfacing at switches.

62. Policing and Patroling.

Policing for Safety of Men.—The policing of a yard is necessary, both from the standpoint of safety and economy. It is not proper that scrap and other large material shall be allowed to lie in the inter-track spaces to be a menace to brakeman alighting from cars, or inspectors walking along the trains intent upon their inspections. While due care will be exercised to clean thoroughly both sides of a track regular policing will be required at stated intervals, and in addition constant attention on the part of track walkers at all times. Whenever a knuckle or drawhead is found it should be removed immediately or at least placed upon the end of the ties. When covers of wells containing stops for watering stock, or charging the air, are discovered to be defective, immediate repairs should be made.

Policing for Conservation.—The item of economy is concerned in yard maintenance, because the value of the scrap reclaimed through every large yard amounts to a considerable sum. This consists almost entirely of parts of cars jarred off in the drill movements, but often contains articles of lost freight for which trace is being made. Due note should always be made of such finds that the loss and damage charges may be reduced. The scrap material should be shipped promptly to the storehouse where reclamation may be made of usable materials and the remainder disposed of in the established way.

Track Walkers.—The larger yards will require the service of more than one track walker; the lamps, if of the 7-day type, which need attention twice a week, can usually be taken care of by one man. It is the custom in some yards for the track walkers to travel in pairs. This is good practice as it permits repairs to be made that would be beyond the ability of one man and which yet do not require several men. If efficient, the trackwalkers will make many corrections which

would otherwise, in time, lead to accident. They will be especially alert to detect and report conditions before they reach a dangerous stage. They should also discover and protect bad track upon which movement may even then be precarious. For this purpose the trackwalkers will always be provided with a red flag.

Lamp Lighter.—The lamp lighters will clean and fill the bowls and trim the wicks so that the indications may be the best possible. He will not leave the lamp until he is sure the light is burning with a good flame and that the targets are adjusted to show properly to trains. Generally the old oil will be thrown out, the cup cleaned, and fresh oil supplied about twice a month. It is seldom proper to cut the wicks and the trimming can best be done by pinching with the fingers. If the wick protrudes too far a considerable amount of oil will be wasted. The lampman will also clean the burners as may be necessary, and will repaint them at intervals, which is usually once in six months. He will call the trackwalker's attention to any adjustment which he is not able to make.

63. Collateral Duties.

Gathering Up Spilled Lading.—The yard forces will often be called upon to render assistance in transportation matters. In transferring freight or picking up spilled lading the method to be followed will generally depend upon the means available. When a hopper car of coal or other similar material is to be gathered up and reloaded upon the same car it will generally be best, in the absence of a work train, to arrange with the yard officers for a flat car which may be pushed along by the men as the freight is loaded. In reloading it upon the car, it will be preferable to do the work with the cars placed alongside each other; but if the yard business will not permit this, it will be necessary to do the work with the cars placed end to end. If wheat or other loose freight is to be picked up, clean canvas bags are of such utility that only a mere mention of them is necessary.

Transferring Heavy Freight.—When heavy materials are to be handled due consideration will need to be given to the plan to be followed. Much labor can usually be saved if proper [illegible] are employed. The work should not be attempted by

an inadequate force, and several of the yard units should be combined if necessary. When the transfer is heavy and beyond the ability of any force of men, a crane or a wrecking derrick will be obtained. Accidents have happened to men because of the foreman unwisely undertaking a transfer that required the use of a machine. The yard forces will be prompt to respond when called upon for assistance in such matters. The business usually is too urgent to await a convenient opportunity, and extended correspondence, or conference, is out of the question.

64. Safety in Yard Work.

Safety of Men.—The safety of men working in and about yard tracks is even more of a charge upon the foreman than it is on main line tracks. No warning is given in yard movement, such as is possible in main line operation. The speed down the humps also is apt to be fast at times. In the classification yards the matter is partly met by closing the switches at each end of the track being worked over to prevent cars being run in upon the men, but they will still be exposed to the danger from cars moving on adjoining tracks. There is also a possibility that they may cause obstruction to the adjacent tracks, especially in tie renewals.

Safety of Movement.—The movement of the hand car and pony truck about the yard tracks requires care to avoid accident. A move with the former should always be with permission of the yard master and even then with full flag protection afforded. The pony car, which can be dumped instantly, may be moved without such permission, but it should always be with due care to avoid trains. The pony car should be protected when the load is such that it might rebound upon the track, as sometimes happens with a rail. It is desirable that all such movements shall be made with a flag at hand. Indeed, it is best that no work be performed about the tracks in a yard except the flag is held ready for immediate use.

65. Preparation for Winter.

Switch Repair.—The critical period in yard maintenance is that which immediately precedes the advent of hard freezing weather. Operation over indifferent tracks may be fairly successful while good weather prevails. In the winter, heaving

of the track, even though it may be slight; freezing of ice in the flangeway of switches, frogs and guard rails; binding of locomotives and cars through frost conditions; the loosening of spikes and other track fastenings; these introduce entirely new problems in the maintenance which pertains to yards. It is of the greatest importance that yard tracks, particularly in so far as concerns the switch connections, shall be brought to the best possible state of repair before winter. The utility gang will concentrate on completing the adjustment of guard rails, the renewal of worn out switches and frogs, the replacement of worn or mashed stock rails, the removal of flange-cut rails from the turnouts, the lining of turnout curves, the adjustment of the ground connections, etc., and they will not neglect the lesser items of switch maintenance.

Digging Out at Switches and Frogs.—The roadbed throughout the length of the switches and frogs should be dug down to the middle of the tie to facilitate snow removal. Dirt will be cleaned away from the pipe lines, through which switches are thrown from a central switch box, in order to permit of water draining away that might freeze in contact with them and thus interfere with their movement. All drains will be dug that may be useful in leading water away from the switches, and for safety these will be covered over immediately. Emergency material will be disposed of so as to be handy in case of trouble and not by any chance become lost under the snow. Tools for clearing snow and supplies for thawing ice will be checked over and any shortage corrected.

CHAPTER XVI

MAINTENANCE PROBLEMS AND METHODS USED

66. Reballasting with Stone.

Inadequacy of Cinder Ballast.—Increasing traffic requirements have made necessary the establishment of faster schedules for both passenger and freight trains. It is well known that cinder ballast, although excellent material when properly maintained for even heavy traffic railways, does not stand up under high-speed movements. It is thus a not infrequent operation in maintenance to replace such ballast with stone, and when the extent of the work is moderate, it generally devolves upon the subdivision forces.

Amount of Raise.—There is usually the opportunity to apply the new ballast by raising the tracks under traffic. Since the old ballast bed then performs the function of a sub-bed, a greater raise than 8 in. is not generally necessary, future raising of the track being depended upon to supply the increased support required by the growing traffic burden. (When gravel is used to replace cinder the raise should be no more than 6 in., to avoid the long delay in becoming compacted which is entailed by a greater lift.)

The Survey and Plot.—The first procedure is to run a profile of one of the tracks, taking supplementary readings on the other tracks at due intervals, and to plot the survey, using a scale of 400 ft. to 1 in. horizontally and 40 ft. to 1 in. vertically. A grade may then be adopted providing for the necessary raise and at the same time eliminating depressions from the general grade. Care should be used to connect the different grades with a suitable vertical curve.

Depth of Stripping.—The old ballast should first be removed to the bottom of the ties in the cribs and for several inches below the bottom of the ties in the ditches. The material as removed may generally be placed on the sides where it will be needed for building up the shoulders and widening the banks

to accommodate the higher grade of the tracks. In some cases it may be necessary to load it on cars to be taken away to a dump, in which event consideration well may be given to the need of widening at other points, or to the filling up of a trestle, avoiding recurrent expense for repairs to the structure.

Precautions Against Buckling.—The tendency when depressions are being raised out is for the rails to become tight, especially if the weather is hot. The extent of open track should therefore be kept to a minimum so that the danger of the rails buckling will be avoided. It will generally be desirable to loosen the bolts in order that all expansion openings may become effective, and it may even be necessary to apply shorter rails in the track at intervals. It is easily possible to keep the work so well in hand from day to day and to take such additional precautions in every operation, that the chance of an accident will be entirely eliminated.

Tie Renewals.—A general renewal of the ties should follow closely upon the stripping of the old ballast. This is obviously economical of cost, and is also a precaution for safety. Since the tamping is at first only of the ends there is the possibility of several of the ties breaking off in face under the traffic when they are inferior. The variable amount of the raise and the somewhat imperfect tamping which is incident to a rush operation, make it essential that the ties shall be in first class condition throughout. It is indeed preferable that they be of white oak; for the lighter woods, or any treated ties, are very likely to fail on the new and irregular bed.

Equipment and Supply.—Since the greatest possible despatch is desirable, provision should be made for cars of a proper type and a transportation officer well may be delegated to the task of seeing to it that cars are always available both for loading up the old material, when it is required, and for maintaining a regular flow of ballast from the quarry to the subdivision headquarters. The engine assigned to the work train should be of the freight type, and especially be provided with a tank of the largest capacity, to avoid leaving the work for water.

Raising the Track.—The heavy raising should always be done under the protection of flags and the attention of enginemen be drawn by a general order to the fact that such work is

in progress. When the average lift determined upon is 8 in., which has been found generally effective for such renewals, the first lift should be 6 in., and this should be shovel tamped at the ends of the ties, the centers being merely filled in. After the traffic through two days has settled the track to a firm bed, a final raise of 2 in. or more, as may be necessary to attain the final grade, should be made in the standard manner. This practice avoids a center-bound condition of the ties and assures a more uniform bed than if two equal lifts of 4 in. each are made.

Lining and Dressing Up.—Immediately after the raising, and before the final back filling is done, the track should be put in proper line, preferably by means of stakes previously established. The work of lining the track is not only easier at that time, but there is a greater degree of safety in the event the back filling should for any reason not be reached the same day. The dressing up of the track to the standard section should follow closely after the final delivery of the ballast.

Ballasting Without Raising.—There are many cases particularly in the vicinity of the larger cities where by reason of many undergrade bridges, or limited clearances with the overgrade ones, no raising at all is practicable. A special problem is thereby presented, which was worked out satisfactorily in the renewal of the two inner tracks of a 4-track road in the eastern region, and the method employed therein may be useful in handling similar cases. The disposal of the wornout gravel removed in this renewal was only possible by loading it on cars to be wasted at a distant dump.

Tie Renewals on Two Year Basis.—The tie renewals were made in advance of any other work so that the stripping might be carried to the proper depth in a single operation. This was not expensive in any event, since renewals in gravel may be made at a cost of no more than two-thirds that required in stone ballast. In order to realize fully on the smaller expense required, the tracks were renewed on a basis of two years' further life for such ties as were not removed.

Tamping the Stone Under the Ties.—Preliminary to the introduction of a ballast bed beneath the ties, the stripping in the tie cribs was carried to a depth of 3 in. below the bottom of the ties, the bed beneath the ties for the moment being undis-

turbed. The ribs of compact ballast remaining under the ties were a sufficient support for the track for a limited number of trains, the condition, however, never being allowed to run over night. After the stone ballast was dumped a thorough tamping was given the track which resulted in a bed of ballast and gravel being formed under the ties. This method was economical and expeditious and its practicability was shown by an entire absence of pumping of the track at any future time.

Drainage through Center Ditches and Cross Drains.—The gravel in the three center ditches was cleaned out to a depth of 6 in. below the bottom of the ties, and cross ditches were cleaned in both tracks every rail length to the same depth as the center ditches. These precautions unquestionably supplied the increased drainage facilities needed to forestall pumping. In the succeeding years the periodical surfacing over of the tracks and the yearly renewals of ties had the effect of adding to the depth of ballast and ultimately freeing it entirely of the gravel.

67. Putting in Service and Maintaining a New Line.

Early Establishment of Full Speed.—It is the rule for restricted operation to continue upon new lines of road for many months after service is begun. This is, of course, an entirely proper precaution during the time the roadbed is becoming settled; but the interference with passenger and freight schedules, especially upon lines of intensive operation, renders desirable the early removal of such restriction. The trend of modern practice in making up time tables is to use the highest rate of speed consistent with safe movement, and schedules, once established, must be maintained thereafter. It has heretofore been considered that an extended period of slow passage over new work was a necessary evil imposed by safety considerations; but upon a careful study of the question it will be found that the required period may be greatly shortened without any risk being incurred. This cannot better be shown than by a careful analysis of a concrete example, the Bristol new line of the Pennsylvania between Philadelphia and New York, put in service near the end of November. The lateness of the season was in itself a live reason for hurrying the establishment of full speed. Although the fill averaged 22 ft. in

On the Bristol New Line

height for more than three miles, service was inaugurated at a speed of 30 miles an hour, which was increased after 36 hours to 50 miles an hour, and after one month to 70 miles an hour.

Arrangements for Throwing into Service.—The operation of connecting up this new four-track line presented incidental points of interest which will be sketched briefly. The new line lies to the north of the old one, and No. 4 is the most northerly of the tracks. The longest interval between scheduled trains in any daylight hour at this point was 35 min., and it was necessary as a preliminary to connecting up each track, to draw it as closely to the existing tracks as possible. This effected a considerable saving in time, not only because there was less track to be shifted, but the maximum lateral throw was greatly reduced. In order to establish complete unity of action at the two ends of the work, which were separated about 3½ miles, a telephone line was installed having besides these two connections only one other, which communicated with the signalmen at the nearest cabin.

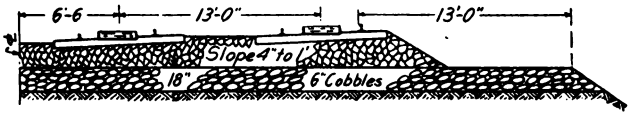
Operating Questions Involved.—When it is known that the total extension of main track necessary for connecting up at the west end was 3,000 ft. with the fill of a maximum depth of 4 ft., and that this track had to be laid in a day and a half, it will be seen that unfailing execution of the prearranged plan was essential, which required close co-operation between the operating department and the track forces. While it would have been possible by working into the night to put in service three of the tracks the first day, it was not considered justifiable, and two were put in on one day and two on the next. The new passenger station was a mile distant from the old one, and, as will be inferred readily, the operating impracticability of having a separate station for the eastward and westward travel was avoided by using No. 3 westward freight track the first day for such eastward passenger trains as were scheduled to stop at this station, these being run against the current of traffic by train order.

The Fill of Gravel Throughout.—There was nothing in the construction of the road to cause its early settlement excepting that the material of the fill was a homogeneous gravel. The filling was not deposited in layers, but was dumped from

trestles built to the height of the sub-grade. The tracks were back filled with stone, although at first the cushion beneath the ties was no deeper than 2 in.

Complication on Account of Track Tanks.—The maintenance question was greatly complicated by the presence at the point of highest fill of track tanks 1,600 ft. long in the four main tracks, which were on a 30-min. curve with 2-in. superelevation. The care of this feature formed one of the important elements of the solution. It is a well known fact that, given a set of men used to daily manipulation of a locomotive at high speed, there will be many who will violate the rules for reduction at specified points. This is particularly true at places where speed restriction is laid on account of scooping water. If high speed is used while this occurs there necessarily results a large waste of water, and careful observation showed that engine tanks were being overflowed frequently through one-third the length of the track tanks. The considerable volume of water that entered the roadbed through this practice introduced a grave element of danger to the stability of the new embankment. This was early recognized and partly met by a general notice limiting the conditions under which engines might take water at that station.

Sub-Grade Drained by Bed of Cobbles.—There still remained a rather heavy burden and to meet this a special construction had been adopted for the sub-bed at the tanks and an extremely generous width of embankment also provided. The former consisted of a carefully laid bed of cobbles 18 in. deep



Cross Section of Roadway at Bristol Tanks

beneath the entire sub-grade throughout the length of the tanks, and for 400 ft. either way from the ends, which alone cost $15,000. The widening, which was done with the heaviest material obtainable, principally dirt from the cleaning of the center ditches and containing much old ballast, extended the shoulders on both sides to a distance of 13 ft. from the gage of

the rail. This construction has also been followed in other similar installations, and a cross-section of the roadway has been introduced as information concerning a practice proved to be effective.

Surfacing at Ends of Bridges.—There were nine bridges throughout the extent of the deeepst fill, which limited the amount the track might safely be allowed to settle. Without the presence of these structures it would have been permissible to assign only a sufficient force to the maintenance which safe and comfortable passage at moderate speed required. By reason of the closeness of the bridges to each other the subsidence had to be met daily as it occurred. The settlement during the night amounted to as much as 2 in., but through the cantilever support provided at the ends by both the service rails and the iron guard rails there was always a comfortable run-off. The total settlement of the tracks was attained at the end of six months and amounted to 18 in. The wisdom of having placed this new line in stone ballast at the start was therein fully shown, since the standard depth of stone ballast was thus secured naturally.

Ultimate Economy of Large Force.—There was assigned to the maintenance of this three mile stretch of new railroad a force of 450 men, and this force was continued during the first ten days of service. The force was gradually reduced as the embankment was compacted, and on January 1 a regular progressive decline in maintenance began. The excess cost of lining and surfacing in January was $2,500, and this diminished uniformly $500 per month thereafter until on June 1 the expense of maintenance was on a par with that of other main tracks. The pertinent fact developed by this somewhat unusual case is that the plentiful labor expended upon the maintenance in the early period of its use greatly hastened the final settlement of the new roadbed. In any construction a definite amount of settlement is inevitable, and as track stresses are known to be higher at fast speed it unquestionably is an advantage to fix the speed as high as practicable and then provide the necessary force to maintain the road. The benefit derived from an early establishment of full service upon this line of road, which carries a daily traffic of more than 200

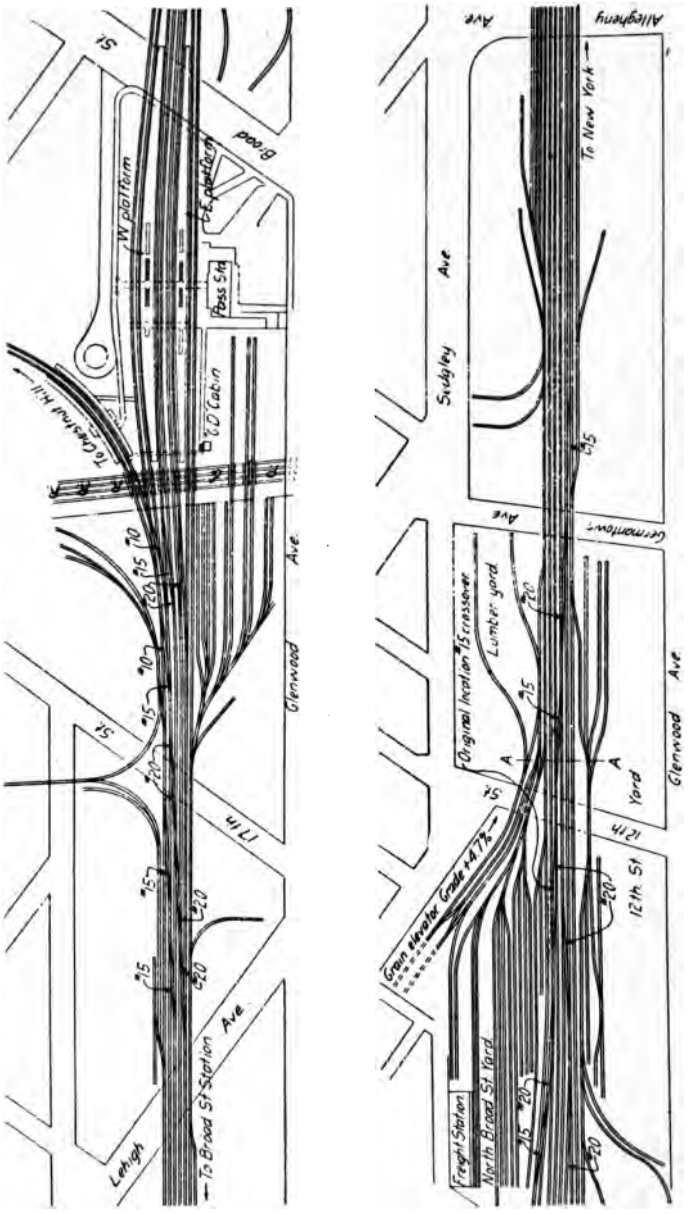
trains, fully justified the considerable expense that was necessary to attain it.

68. Raising and Shifting a Six-Track Main Line.

Maintenance Problems.—In addition to the interesting structural and architectural features of the improvements made by the Pennsylvania at its North Philadelphia station, there were many and varied problems presented to the maintenance department for solution during the progress of the work. Thus, although the improvement extended over but one mile of line, it included typical problems of alinement, grade, switch connection and bridge adjustment, and involved the raising of a six-track main line system and numerous connecting yard tracks under a heavy traffic. A description of the manner in which the track work was handled under traffic on a busy road should prove instructive.

Advantages Sought.—The object of the improvement was three fold: First, an increase in facilities by providing an additional track for passenger traffic in each direction with high island platforms, and an additional drill track on each side of the main track layout, these being used also as freight running tracks; second, the reduction of the grade at the station from 0.7 per cent to 0.3 per cent to eliminate delays caused by the difficulty of starting the heavier trains on the former grade; and third, the necessity of renewing three bridges in this section which were inadequate to carry the increasing train loads.

Problem of Gradient.—The ideal maximum grade on the division is 0.6 per cent. By the use of this grade west of the station between Seventeenth street and the crossing of the Philadelphia & Reading, with a vertical curve directly over the P. & R. bridge, the increased depth of floor system required for the new bridge at the latter point was secured. The 0.3-per cent grade adopted for the larger portion of the station platform length provided the greater depth of floor necessary for the new bridge over Broad street and supplied some additional headroom for the street. The continuance of the 0.6-per cent grade east of Broad street connected at Allegheny avenue with the opposing grade of 0.1 per cent by a long vertical curve caused the greatest problem in the whole elevation. The maximum change in grade was 3 ft. 10 in., and



Layout of Tracks at North Philadelphia

the average 3 ft. The existing bridge at Germantown avenue was raised to the new grade and later renewed and the Twelfth Street bridge was encased in concrete to carry the deeper roadway.

Density of Traffic Required Sunday Work.—The raising of the main and yard tracks was an interesting problem for the maintenance department on account of the density of traffic. The week day passenger schedule included 200 trains every 24 hours, one-half of which moved between 7 a. m. and 5.30 p. m., during the working day. The freight traffic which was handled almost entirely upon the inner tracks amounted to 30 trains during the day period. Some of the more important freight trains were run upon the outer main tracks, but generally at times when the greatest intervals occurred between passenger trains. The extent of this traffic practically precluded any raising of those tracks on week days except that on No. 4 track between the hours of 6:30 and 8:30 a. m., two one-hour open periods occurred which were duly utilized. The Sunday schedules not only carried one-third fewer trains, but also had longer open periods. These were necessary both to provide the opportunity for making a substantial lift, and also to unload on the main tracks the material necessary for the raising. The yards shown on the accompanying drawing are in constant use on week days for a very heavy local business and for the considerable traffic at the grain elevators, but are idle on Sundays. For this reason Sunday was also the only day when certain of these tracks could be raised.

Organization for Track Raising.—Gangs furnishing a total of 100 men for the main tracks and 60 for the yards were used for this Sunday work, a different lot of men being used on alternate Sundays. An itinerary was planned for the work train which provided for periods varying from 30 to 45 minutes successively upon No. 1 and No. 4 tracks as opportunity offered and at other times in the yards on either side; care, however, being always taken to utilize intervals in the late afternoon for dumping material necessary to back fill the main tracks which had been raised during the course of the day. These movements were facilitated by the presence of cross-over switches at each end of the work. During the time that

actual raising was in progress all trains were slowed by flags, to which attention had been drawn by a general notice. Upon the completion of the day's work the tracks were left in fit condition for regular service and at no time was any speed restriction laid by order.

Progress Planned.—The aim of each Sunday's work was to attain an average raise of one foot through a half mile of both passenger tracks, which with the settlement from traffic of the following week netted about 9 in. of permanent lift. The operation on week days consisted mainly of moderate raising of the freight tracks, also under protection of a flag, and of the yard tracks whose use could be spared, and of such surfacing of the tracks already raised as might be necessary. The usual consumption of material was about 7 cars each week day and 18 cars on Sunday. In all, 610 cars of cinders and 155 cars of stone were required for the work. The material was all supplied in hopper-bottom cars, which greatly facilitated the unloading.

Equating a Grade Through a Train Length of Distance.—The grade of the main track system had to be adjusted to the grade of the yard and elevator tracks connecting with it. The grade which existed on the elevator tracks was already the maximum allowable, the heaviest drill engines being only capable of moving three loaded cars up the 4.7 per cent grade. The only possible scheme of continuing the connection with the No. 5 track was to raise this track as little as the extension of this grade eastward to the connection would require. This in turn necessitated a separation of grades between the No. 5 track and the remaining main tracks. An 0.8 per cent grade was established for the No. 5 track, between Broad street and the junction with the yard track near Twelfth street. This distance is just half the maximum train length and, by using a 0.6 per cent grade eastward from that point, the resultant grade for the maximum train length was kept at 0.7 per cent. This was considered the maximum permissible for this track, which is used rather frequently as a freight running track.

A 20-in. Difference of Level for Adjacent Tracks.—This separation of grades between tracks No. 4 and No. 5 required that the latter should be as much as 20 in. lower than No.

4, but as this is little more than the depth of the standard shoulder it has worked no disadvantage from the standpoint either of operation or maintenance. The No. 0 track was also placed 20 in. below the main track grade, and this arrangement was of great advantage in establishing proper connection with the various yards and industrial sidings, many of which were on trestle work. No greater grade than 2 per cent was required, and all intersections were provided with suitable vertical curves.

Tilting a Four-Track Bridge.—A special problem was presented in the raising of the four-track bridge carrying yard tracks across Twelfth street. The elevation of the southerly track on this bridge was fixed by the connection which this track makes with the main line immediately east of the bridge. A similar elevation on the northerly track would have required a grade of 4.7 per cent on the lumber yard lead. As the business of this industry amounted to about 600 car loads per year it was desirable that this grade be improved. It was finally decided that a moderate downward inclination of the bridge toward the north would not introduce any great disadvantage either in operation or maintenance, and this allowed the northerly track to be lowered enough to secure a 2 per cent grade instead of 4.7 per cent for the lumber yard siding.

Shifting of a Two-Track Line.—The operation of shifting the two Chestnut Hill branch tracks to their new position on the new bridges 32 ft. north of the old location and of shifting one of the passenger platforms which forms a part of the improvement, was carried on by a special organization. The westward traffic on this branch, excepting one train which was run against traffic, ceases at 11:20 p. m. Two gangs of men were employed for this work, one working from 10 p. m. until the following noon and the other from 6 a. m. to 8 p. m. The westbound track was laid during the night, while there was no traffic, and in the morning both eastbound and westbound movements were made over the one completed track, while the relocation of the eastbound track and platform was carried on.

Although it would have been possible to establish a circular curve between the Philadelphia and Reading and the

Sixteenth street bridges, it was decided to increase the curvature at the platform in order to continue a curve of larger radius at Sixteenth street, the curvature gradually increasing from this point to the platform. This arrangement is of benefit to operation as the trains naturally go into the station under some headway which must gradually be reduced to a stop. The curvature varies inversely as the speed, giving the curve somewhat the form of a parabola.

Absence of Casualties.—Although the force of signal men and track men employed frequently reached as high as 250, and these men were required to work on tracks which were handling 40 branch line passenger trains in addition to the 100 main line trains, 35 freight trains and almost continuous drill movements on No. 0 and No. 5 tracks, the work was accomplished between March 1 and July 15 without a casualty of any kind. This was attained by unceasing vigilance and fidelity to established rules of safety. The work was carried out by close co-operation between the chief engineer's organization and that of the division superintendent.

69. Improving a Subdivision After Neglected Maintenance

Deterioration of Roads.—The labor situation was so acute during the period of the war that maintenance in many sections had to be confined practically to inspection of the track. The inevitable result was a slow but certain deterioration in the riding qualities of nearly all roads. The deficiency did not generally progress to a degree that endangered the movement, although in some cases a reduction in speed schedules became necessary. It rather involved certain obscure defects difficult to determine properly. The effects were felt on main lines more than on branch lines, because the latter, by reason of being farther from the centers of industry, were less affected by labor conditions.

Improvement in Industrial Conditions.—The situation has now changed for the better, and the maintenance department is confronted with the problem of making the repairs best calculated to achieve a rapid improvement, especially in the item of line and surface. The advance in wages being paid the foreman is drawing a better class of men to that position and a larger wage, better housing conditions and more considerate treatment should eventually attract an adequate

number of laborers to railroad employment. It is therefore believed that a discussion of the program followed in the upbuilding of an important main-line subdivision, over which the traffic was of an extremely critical character, and which had suffered from neglected maintenance, will be constructive.

Determining the Cause of the Defective Maintenance.—A mere visual inspection of this piece of road would have shown an exceptionally good condition of the rail in the main tracks and a fair condition of the ties. Indeed, in no physical respect was maintenance greatly below the standard. The fact was undeniable, however, that good riding was not obtained. A casual study of the recent history of the subdivision plainly indicated the principal causes of the deficiency. It was learned that raising of the track had been discontinued some years before, the main tracks being in consequence center-bound throughout. The general line also had suffered through failure to apply proper methods to its maintenance. While the ties were good, judged solely by the standard of safety, there were many that had outlived their usefulness in holding the surface. These were "spike killed," tamped to a rounded base, or so far deteriorated that the original No. 5 size had become more nearly the No. 3 size. Naturally there were some isolated spots that required prompt renewal and these were sought out and given the necessary attention.

Relining the Tangents.—The first work actively undertaken was to reline the subdivision. The tangents were tacked, using practical methods in the work. The most potent defect of tangent lines as usually established is the deflection due to error of the instrument and to personal equation. The former may be avoided by using foresights entirely, the latter by setting only points that are within about 300 ft. of the instrument. It is generally necessary that each track be considered separately, and a line 5 in. from the inner side of the rail base is the most convenient. The flagman should be stationed at the remote end of the tangent if practicable; otherwise at a summit in the grade, with his back to trains, an attendant protecting him. He should wear a white shirt or light blouse, so that when the rod cannot be distinguished

the instrument may be set in the middle of his body placed exactly over the point.

When the sight is obtained a rodman sets points about 100 ft. apart, but no farther than 300 ft. from the transit. The instrument is then moved to the point last set and, after foresight upon the distant man, or the rod, which eventually will be seen, points are again set to a further distance of 300 ft. from the instrument, when a new set-up is made. This is continued until the entire tangent is tacked. The continual foresight nullifies the instrumental error and the short sights in setting the points eliminate the personal equation. It is not usually necessary to set stakes and in fact it is preferable to omit them, as they are apt to be used afterward when they may have been disturbed. A convenient method is to withdraw the spikes from a tie and set the tack directly upon the tie, shifting the tie to its proper position after the lining has been completed.

Adjusting the Curves.—The improvement of the subdivision involved in an even greater degree the correction of the curve defects, not only those of the line, but of superelevation also. The string was used to good purpose on all the curves, the ordinates almost without exception being taken by the foremen, and in some cases worked out by them, and the throwing was done promptly after figures for the amount of throw had been given. These were written upon the ties and an arrow added to indicate the direction of the throwing. Stakes were set in only a few cases, the measure of the throwing usually being taken with a pole from the adjoining track. The proper amount of the superelevation and the detail of the run-off were determined for each case.

The curve correction involved adjustment of two light curves over which the riding had been particularly unsatisfactory. The curves were quite long, their combined length being one-eighth that of the entire subdivision. One was 18 min. and the other 20 min., and both carried an elevation of 1 in. The test showed the curvature at certain points to be as sharp as 40 min., for which 1 in. superelevation was of course totally inadequate. The lining required a throwing as great as 10 in., and the curves were given elevations of

1¼ in. for the 18 min. curve and 1½ in. for the 20 min. curve. When the adjustment was completed complaints which had been frequent ceased entirely.

Correcting the Grades.—A vigorous prosecution of tie renewals was then taken up and the practice was pursued as far as possible of following this work with a 2-in. raise of the track. While this was partly for the object of providing an additional depth of ballast, it was mainly to relieve the center-bound condition of the track. A further advantage was obtained by eliminating the numerous dips or sags which had crept into the grade, the presence of which precluded fine work either in lining or surfacing. At special points where an unfavorable grade had developed, or where there was need for greater raising than a mere surface lift, a profile was run with the level instrument, the existing grade platted

Maintenance of Correct Grade Through Interlockings

and a new grade determined, care being taken to join all changing grades with a suitable vertical curve. Stakes were set every 100 ft. indicating the grade of the top of the rail.

Special care was taken to correct the grade through interlockings. The switch layouts had not been raised for a number of years, mainly because of lack of force, while desultory raising had been done from time to time at the approaches to such points. This practice had the natural result of developing finally a depression through the switches, which is an exceedingly unfavorable condition. Wherever possible a continuous grade was laid throughout the limits of the interlocking, even though considerable expense was required for raising the foundations of the signal work. The heavier raising was done with floating gang labor, and ballast was available for prompt back-filling of the tracks.

CHAPTER XVII

ECONOMICS OF TRACK LABOR

70. General Conclusions Based on Experience

Economies Developed in Special Problems.— The author hesitates to advance any fixed conclusions regarding this important question, as it is the main division of work being studied by the Committee of Economics of Railway Labor of the American Railway Engineering Association. It may be permissible, however, to discuss those features of the subject which have come directly under his supervision. Several points were especially brought out by a brief discussion of the specific case. Thus, it was shown that Sunday work has a large element of economy in districts where the week-day traffic is very dense. It was pointed out that the use of an extremely large force for maintenance of a new line resulted in early attainment of full service and consequent economy in the after maintenance, and that immediate application of stone ballast in a main line effected a considerable saving in the future repairs. It was proved that opportunities for economy are presented in the operation of stone ballasting the tracks in high-speed service. There are many other processes in M. W. & S. work wherein a study of economics will result in a material saving in the expenses.

Track Forces Relieved of Irregular Duties.—The track forces are often called upon to perform service which is in no way connected with their regular work. Especially is this practice in effect on suburban passenger roads. One such line was inefficiently maintained because a large part of the section labor was given over to attendance upon the agents. This work ranged from carrying out ashes in winter to sprinkling the streets in summer. It was determined that these small matters were part of the agents' duties; and, when the section force was relieved of the constant drain of this

attendance, it was able to maintain the track. A somewhat similar item of waste was found in the policing of delivery yards. There are many such places which the continual labor of one man six days per week will keep clean. It is manifestly not an economical practice for a force of eight men to be taken one day per week to the yard to do this cleaning. It is practically certain that the entire day will be so used; and, besides, there is the considerable time lost by the gang in going to and from the work.

Sufficient and Uniform Forces.—There is an element of economy in the assignment of an ample force to a section and the arrangement of the work so that the force will remain uniform throughout the year. It is possible to move floating gangs about to attain uniform maintenance, and such help will always be necessary, but it is not an economical practice. A better class of work will be obtained when the ordinary repairs are made by the section force. The laying of new rail and ballast cleaning out of face are variable elements which may properly be assigned to extra gangs. The renewal of ties, the lining and surfacing of track, and the routine work of the section, should be the distinct duty of the track force.

Practical Length of Sections.—The length of the section then becomes an important item in the subdivision organization. It is economically wrong to make the length so great that proper detailed attention cannot be given to every feature of the repairs. It is not enough that corresponding force be allowed. There is a very definite limit to the amount of track that can be covered efficiently. Experience in this matter was had by the author on a 4-track main line of the highest requirements. The sections were formerly 3 miles in length, and included besides the 12 miles of high-speed main track, an average of 2 miles of sidings and 15 switches. The maintenance was below the average of the division, and it was determined that the territory of the foremen was too great. The sections were reduced to two miles in length, when concrete results were immediately shown by the attainment of the division prize of $800 for excellence of track the two succeeding years.

Semi-Skilled Work Allotted to Track Forces.—There is now crystallizing into shape the thought that a considerable economy may be effected by training the section forces to perform certain items of semi-skilled work, so as to avoid the necessity of higher priced mechanics traveling long distances to perform simple items of repair. This plan was casually tested on a supervisor's division which had the advantage of a blacksmith shop and a carpenter gang. The subdivision was at the oposite end of the division from that where the mechanical department headquarters were located. It became the practice for the supervisor's force to respond to many calls for simple repairs that had previously been made by mechanics traveling as much as 80 miles.

There was in addition a special-duty man at the supervisor's headquarters whose main work was that of relief engineer. This man was an all-around mechanic who could perform almost any of the small jobs that constantly turn up about a railroad. The saving to the bridge and building and mechanical departments by his attendance was considerable, and the supervisor's department was nowise inconvenienced thereby. It is doubtful if this plan can be developed generally among the section forces, unless a differently equipped set of men are employed as track laborers, which does not at present seem practicable of attainment.

Special Duties Performed by Designated Employees.—A considerable economy in the work of cleaning stations is obtained by relieving the track forces of this duty and having it performed by special duty men or by women. The latter usually furnish better service for the lighter cleaning, and there is often a widow of a trackman killed in the service, who is both able and willing to do the work. The scrubbing of the floors and the outside cleaning and policing can be done by a regularly assigned laborer, who precedes the woman one day. The tour of both is regulated by a fixed schedule, usually providing for attendance of each one day per week. When the stations are of less importance, the entire work may be done by one man, who likewise has a definite schedule. By this practice no time is lost from the section work and the regular routine of the track repairs is not encroached upon.

The same advantage is obtained by having special relief men to fill the places of crossing watchmen, bridge tenders and others upon the occasion of their regularly designated days of absence. These are usually two per month and one such man could thus relieve at about twelve different points. By a careful arrangement of the schedule some of these could be night shifts, along with the day assignments. The advantage of this system is that the relief thus becomes a matter of routine, and the service is performed by one who is entirely familiar with the duties. There are many other items wherein the economy of labor may be shown, and they have been brought out in the broader consideration of the special items of work.

CHAPTER XVIII

SPECIAL DUTIES IN THE M. W. DEPARTMENT

71. Determining the Cause of Train Accidents

Preliminary Investigation.—For the object of obtaining a correct determination of the cause of a derailment, not only to place the responsibility but to apply at once the needed correction, if any defect of track is found, all those concerned, whether officer, foreman or car inspector, should approach the matter with an open mind. The preliminary investigation will not consume much time, and is entitled to precedence for the reason that subsequent moves may result in the cause being covered up, or may distort conditions so that a false result might be reached.

The first duty at a wreck, after it has been ascertained that no personal injury has resulted, is to make diligent inquiry as to the exact details of the movement just preceding the accident. The exact point of derailment can almost always be determined from marks on the rail or ties and the gage and level of the track should be tested on either side of this point. Similarly, all track fastenings should be examined. and the general line and surface observed. Special note should be made of pumping joints which might become much lower under wheel loads than appear on the surface. Finally, a close examination of the lading and the equipment should be made to determine if these may have caused or contributed to the derailment.

Frequent Causes of Accidents.—The common defects in cars which cause accidents are worn or broken flanges; worn treads; broken arch bars; bent axles; loose wheels; draft rigging pulling out; brake rigging down; journals burnt off; and center or side bearings dry or rusty, or lacking or exceeding necessary clearance. Frequent causes which concern the movement are improperly placed or shifting loads; excessive speed or rough handling of the train; bursting air

hose, or a "kicker" in the train; and operation around curves that are prohibited. For the information of the supervisor and foreman, the accepted M. C. B. practice is given for items in which measurements are required to determine if limits have been exceeded.

Side Bearings.—Side bearing clearance should be observed carefully on cars with metal body and truck bolster; when balanced on center plates, it is considered good practice to have $\frac{1}{16}$ in. to $\frac{1}{8}$ in. between all four bearings; if the car is found to be down hard on one side, the total clearance should not be more than $\frac{1}{4}$ in. on the opposite side. On cars with wooden body and truck bolsters, or composite wood and metal bolsters, it is considered good practice to have $\frac{1}{8}$ to $\frac{1}{4}$ in. clearance between all four side bearings when balanced on center plates, and when a car is bearing on one side, not more than $\frac{3}{8}$ in. clearance on the opposite side. For passenger equipment of rigid design, the proper side-bearing clearance is $\frac{1}{32}$ in. on each side, or $\frac{1}{16}$ in. on one, if the car is hard on the opposite side bearing.

Wheels.—When wheels are under a car of less than 80,000 lb. capacity, the flange is worn to an extent justifying removal if $\frac{15}{16}$ in. thick or less, or having flat vertical surfaces extending more than 1 in. from the tread; (this also applies to all steel and steel-tired wheels); and for cars of 80,000 lb. or over if 1 in. thick or less, or having flat vertical surfaces extending $\frac{7}{8}$ in. from the tread. Wheels when cast prior to 1907, are out of gage if less than 4 ft. 5¼ in. between backs, or more than 4 ft. 6¾ in. between gage of one and back of the other, or less than 5 ft. 4 in. out to out of wheels; when cast since 1907, the respective dimensions are: less than 4 ft. $5\frac{3}{32}$ in.; more than 4 ft., 6 29/64 in., or less than 5 ft., 4 in.

Couplers, Etc.—Couplers on either freight or passenger car equipment are out of adjustment if less than 31½ in. or more than 34½ in., from top of rail to center line of coupler shank. A truck is defective if any part of the truck frame or attachments is less than 2½ in. from top of rail. For convenience, the ends of cars are designated as "A" and "B," the "B" end being the end which carries the brake shaft; in case there are two brake shafts on the car, the end toward which the piston push-rod travels is the "B" end.

Derailment at a Switch Connection.—When the derailment occurs at a switch, it should be noticed whether or not the point in question fits up snugly to the stock rail, and if not, whether an obstruction has lodged between the switch point and stock rail, or the ground connections have any lost motion, or the switch is otherwise out of adjustment. The gage should be tested both ahead of and through the connection, and an accurate measure be taken to determine the exact guard-rail gage. This is the distance between the gage line of the frog and the flange side of the guard-rail and should be 4 ft. 6¾ in., whatever the track gage may be. The condition of the switch ties should also be noted. A careful observation will be necessary to determine if irregular elevation is a factor, and this is especially required when the derailment is just back of the switch ties. A close examination of the switch point will be in order, particularly if the derailed wheels show flanges that are worn close to the limit. To determine this point definitely an M. C. B. wheel gage, if available, should be applied to the flanges in question.

Derailment on a Curve.—When the derailment is on a curve a somewhat more detailed examination is required. Since the exact point of derailment can almost always be determined, it is the practice on the Pennsylvania to require that 7 stations be located back of the point of derailment and 3 stations ahead, each 31 ft. in length, and the middle ordinate obtained at each of the points with a 62-ft. string. With a correct level and gage the superelevation and the exact gage are measured at these same points. The track is sighted to discover if any low joint or bad kink is in evidence that might escape the other tests. Not infrequently the cord data are required every 15½ ft. and occasionally every 11 ft. The condition of the rail is sometimes a factor and in that event a tracing of the section at the point of accident is required. All observations should be noted so that a slip of the memory may not cloud the issue. The transportation and motive power departments should similarly make a close investigation as regards the movement and the equipment.

The Accident Committee.—The most satisfactory method of arriving at the causes of accidents is to place the determination of all such occurrences in the hands of a committee

consisting of an assistant trainmaster, as chairman, with the track supervisor and a representative of the motive power and car departments as members. In case of disagreement, a meeting with all the facts brought out from the standpoint of each will almost always result in a fair conclusion being reached. In the event of failure to agree, a representative from the higher departments might be called upon to offer his views from personal examination of the situation and the known facts. In all cases insistence is had that the committee shall finally reach a determination of the matter.

72. Patrolling the Track

Need of Track Watching.—The patrolling of the track is the essential duty of the track-walker. It is necessary that

The Trackwalker Should Travel Facing Traffic

the detailed condition of the railroad shall be observed frequently. Many parts drop from cars in transit, and must be removed promptly; car doors and even roofs are blown upon adjoining tracks where they will be likely to entail accident; objects protrude from cars standing on sidings, which may cause personal injury; the track structure is subject to the occurrence of sudden defects whose presence cannot

be anticipated; many rail failures are preceded by signs of weakness which a watchful eye can detect; in warm weather the track may buckle suddenly from expansion; in cold weather it may pull apart from contraction. To protect as far as possible against such obstructions is the main business of the trackwalker. For this object it is required that he shall always be provided with a red flag, and he should also carry torpedoes and fusees. He should understand fully the use of signals, and be prompt to supply the necessary protection.

Routine Duties.—The routine duties of the trackwalker are: To tighten the odd bolts he finds loose and to replace any that are broken or missing; to tap down the spikes that are beginning to come up in face; to gage in a rail that is commencing to spread; to discover and replace cracked splices before they become dangerous; to look over frogs, switches, and guard rails; to repair broken bond wire connections; and, in general, to observe everything that concerns the safety of the track. He should repair promptly such defects as he can, and bring to the attention of the foreman those that are beyond his means.

Incidental Duties.—An important duty of the track-walker is to see that switches are set and locked for the main track and, in the event the lock is found damaged or missing, to supply a new one immediately. He should also see that the telephone boxes along the line are properly closed and locked. It is usually his duty to clean, fill and light the switch and derail lamps, making sure that there is oil enough in the fonts to burn the required time, that wicks are adjusted to give a clear light without smoking, and that the lamps face so as to present a good indication to the engineman. Where derails are in use but are not connected with the main track switch, he is required to see that they are properly thrown whenever any cars are standing on the siding. Where derails are not used, he should note whether or not the cars fully clear the main track and make sure that the brakes are applied. In case he finds cars pushed off the dead ends of sidings he will report the matter promptly. He should examine the cars along the main track to ascertain that doors

are properly secured and that no other obstructions decrease the inter-track clearance.

Protection of Property.—He is required to examine buildings and other property of the company and to protect them from fire and other damage. At certain stated times he is required to sweep off the cinders accumulating on the station platforms, and in some cases it is necessary that he clean, fill and light the platform lamps. In the winter season he must sprinkle salt upon the platforms at isolated stations to avoid accident to passengers. He must know the limits of the Company's ground so he can warn off trespassers, and he should report to the foreman when he finds anyone using the right of way improperly. He should be alert to extinguish grass fires before they gain headway. He should be careful to put out fires burning in the ties, as this will not only save the company the cost of new ties but the labor of putting them in track, which is nearly equal to the cost of the new ties. By burning up old paper, old waste, leaves, etc., he can do a great deal toward making the railroad look tidy. He should watch for openings in the right-of-way fences through which stock might enter upon the railroad and either repair them temporarily or call the matter to the attention of the owner. By his attention to this matter the trackwalker will acquire and keep the goodwill of the farmers along the line.

Tamping Low Joints.—It makes for efficiency if the trackwalker is careful to observe low joints and deficient line. It is not expected that he shall take note of the detailed line and surface, for that is strictly the foreman's duty; but he should report places where the track is becoming rough, in order that the defect can be corrected promptly. With the assistance of a man from the gang, he should whenever possible tamp the low joints, and he should especially see to it that insulated joints are tamped frequently. Unquestionably the detailed repairs made by the trackwalker are the means many times of averting an accident. For this duty he will always be equipped with a hammer and track wrench, and will carry in his bag a small supply of spikes and bolts, as well as fusees, torpedoes and a red flag.

Night Patrolling.—The duties of the night patrolman are

necessarily restricted to the actual patrolling of the road. To require him to make any repairs would expose him to too great a risk, his danger being considerable even under the most favorable conditions. To minimize his danger he should carry a protector lantern with a light shining from the rear, so that the engineman may discover his presence. This light should be so arranged that it can be changed in a moment to a stop indication. Safety rules require that he shall always travel facing the direction from which trains normally come, but since they may be operated against the current of traffic, he must keep a sharp lookout in both directions.

Checking Performance.—Except in isolated situations, there does not appear to be any need to check the day trackwalker

Where Efficient Patrolling is Specially Needed

by clock or otherwise, but this is always required in the case of the night patrolman. Although the clock system supplies a satisfactory means of recording the observance of the established tours, tests are also necessary to determine that the patrolling is not of a perfunctory character. These tests

are not so essential in the case of the day man, because he is constantly under the eye of the foreman, and his work can be gaged by its results. Where the duties of the day watchman, however, are solely those of patrolling at dangerous points, the clock system should be used, since in the event of a slide causing an accident, the record would be required to prove that the tour had been followed faithfully.

Track Experience Needed.—Both the day and night patrolmen should be experienced track men, possessed of good intelligence. The occasion may arise at any moment when they will have to determine quickly upon a course of action. Especially should they be alert to protect the track most immediately endangered. They should be prompt to call the foremen and men when a sudden emergency, such as a snow or heavy rain storm, requires their attendance.

A Knowledge of First Aid Desirable.—The day or night watchman may be called upon to minister to an injured person found along the tracks. He should have some knowledge of first aid, as thus he may be the means of saving a life. He should take prompt action to notify the superintendent from the nearest telephone in order that the injured one can be taken to a hospital by the first train. In electrified sections it is especially important that he should have a working knowledge of resuscitation from shock. It is by virtue of the many important duties required of him that the trackwalker may reasonably aspire to ultimate promotion to assistant foreman and foreman, and the supervisor will always give due consideration to his services.

73. Protecting the Highway Crossing

Physical Features at the Grade Crossing.—Increased attention is now being given the matter of providing uniform and effective protection at grade crossings. The subject has become a live one, not alone by reason of the nearly universal use of the highways by automobiles, but also because of the natural increase of population. Much study and thought have been devoted by the higher officers to the physical requirements of the crossing. It has been determined that the cross-arm type of warning sign is the best; that these should be supplemented with cautionary signs at least 200 ft. back

from the crossing; that gates should be painted in alternate diagonal stripes of black and white; that the grades leading to the crossing should be made as easy as possible; and that especial attention should be given to enlarging the view, both to the crossing from the engine and to the train from the approaches of the crossing.

Source of Supply for Watchmen.—The human element in the protection of the crossing is of equal importance with the physical aspect, and this matter is usually the direct concern of the maintenance-of-way officer. While nominally the crossing watchmen are placed by the rules under the charge of the captain of police, they are practically everywhere the supervisor's responsibility. The crossing watchmen are therefore almost invariably recruited from the track forces, the character of which has undergone a radical change in the last few years. The supply of native American laborers is not now sufficient to fill the vacancies occurring among foremen and assistant foremen, and thus many crossing watchmen are of necessity foreigners. It is of course essential that the crossing watchmen should in all cases be able to speak English, at least so as to be understood, and he should be able to write it also.

Selection of Watchmen.—The selection, training and observation of these employees is a most important duty of both the supervisor and the foreman, and involves attention also on the part of the medical and transportation departments. It is the supervisor's business to examine into the man's intelligence; to inquire diligently as to his general health and his mode of living, especially as regards sobriety; and to estimate his probable loyalty to duty. The medical department examines him as to his eyesight and hearing, the transportation department as to his knowledge of such of the rules as he will need to use. The approval of all of these should be essential to appointment. Equal care should be had in the selection of relief men to fill the places of the regular men upon their assigned days of absence.

Hours of Protection.—The instructions reprinted herein have been adopted as the basic practice in protecting crossings on the Pennsylvania. Observations are made frequently to

Special Instructions for the Government of Crossing Watchmen

1. The crossing watchman must understand that his first and most important duty is the saving of human life.

2. The hours of duty at this crossing for week days are from —— a. m., to ——p. m., and from ——p. m., to —— a. m., or for week days from —— a. m. until after the passage of Train No. —— unless more than —— minutes late. On Sunday from —— a. m., until —— p. m., and from —— p. m., to —— a. m.

3. When two or more watchmen are employed during the day or night there must always be one on duty. When both day and night watchmen are employed they must not leave their posts until relieved.

4. The crossing watchman reports to and receives his instructions from the supervisor.

5. He must provide himself with the proper appliances for giving signals, keep them in good condition, understand their use, and must have with him while on duty, copies of the current time-tables and supplements, if there are any.

6. He must not permit unauthorized persons in or about the premises, must not read papers or books while on duty, nor unnecessarily engage persons in conversation. He must keep his watch house and surroundings clean, and the crossings and foot walks clear of dirt, snow and ice. This work must be done at such times as not to interfere with his duties as watchman.

7. He must, as far as possible, prevent persons from trespassing on the Company's property.

8. He must exercise care to insure full portection at the crossing when trains are approaching.

9. He must, in case of accident to vehicles or pedestrians on the crossing, or vehicles colliding with and damaging the gates, secure the names or addresses of parties to the accident, together with names and addresses of witnesses, and in all cases immediately report by wire to the superintendent.

10. He must, whenever the driver of an automobile crosses at reckless speed or fails to heed a warning and thereby incurs an improper risk, accurately note the license number of the automobile and report fully the circumstances of the case.

Superintendent.

determine that the rules are properly posted in the watch house, and that the hours of the watchman are shown correctly. In the event of an accident occurring while protection is suspended, a copy of the instructions will supply valid evidence for the Company's defense. A sign, posted outside the watch-box giving notice to the public of the hours during which the crossing is not protected, is necessary in order that the traveler may know that at such times his safety is entirely in his own hands. In all cases wherein report is made of automobiles infringing safety rules a letter is sent by the superintendent to the owner calling his attention to the matter.

Points in Protecting Crossings.—In the training of watchmen to a full knowledge of their duties and responsibilities, the important points to be taught them are: First, that gates should be lowered in sufficient time before the arrival of a train and should not only be kept down until the train has passed but until it is found that no other train is approaching; second, that in flagging a crossing where there are no gates it is generally best for the flagman to stand on the farther side of the railroad from that upon which the train is coming, as he can thus intercept travelers who might overlook a more distant train approaching from the opposite direction; third, that he should observe those who are waiting to cross and give particular attention to any who seems to be careless or unmindful of danger; and fourth, that children should be especially safeguarded.

Proceed Signals to Travelers.—There is a wide difference of opinion as to whether or not the watchman should give proceed signals to the traveler on the highway. When the hand disc bearing the word STOP is used in place of the flag, it would seem that its withdrawal should generally be sufficient notice to come ahead. With the use of the flag, however, it is hardly possible to move the traffic expeditiously unless the furling of the flag is accompanied by a signal with the hand. It is believed that the matter is one where no fixed rule is practicable and where the judgment of the watchman should be the best guide.

Handling Gates.—The watchman should be directed to pass the traffic on the highway promptly, so that his crossing may

not become congested. To this end the gates should not be lowered unnecessarily long before the arrival of the train, nor kept down after the way is found to be clear. The practice of keeping the gates down continually and raising them only when necessary to pass vehicles is wrong and should not be permitted. It leads pedestrians into the habit of walking around or under the gates and is productive of accident. Not only should the watchman handle his gates properly, but he should always be in a position to observe everything that takes place while a train is passing. In order to be able to attract the attention of drivers or pedestrians who might not hear his shouted warning, he should be provided with a shrill whistle, which he should use only in such an emergency.

Flagging Trains.—The crossing flagman may be called upon to flag a train because of an automobile stalling upon the track, or an animal getting fast in the crossing flangeways, or some similar trouble. He should have his red flags and his red lanterns in such a place that he can make use of them instantly, and the red lantern should be kept lighted at night. When it is necessary for him to leave his post to flag a train, he should if possible get a responsible bystander to assume his place at the crossing. If both tracks are suddenly endangered, he should ask a bystander to assist him in flagging trains.

Observing Hours for Protection.—While it is of the greatest importance that the exact program of protection established for the crossing shall be carefully observed, the supervisor should have full authority to afford additional protection when required by an unusual traffic of temporary duration; or, similarly, to place a watchman on occasions when the protection would normally be withdrawn. The crossing watchman should never be late at his post, and he should close the watch box when the specified hour for withdrawing has arrived. When there is continuous protection he should not depart until the other flagman relieves him. He should not leave his crossing during the hours of protection unless the trackwalker or some other reliable person is at hand to supply his place while he is absent.

Loitering.—The rule prohibiting loitering about the watch-box is one that must be observed. Idle persons distract the attention of the watchman and of travelers about to use the crossing. The flagman should call the attention of loiterers to this regulation and require them to heed it. To forestall the need of such action, there is usually posted in a conspicuous place upon the watch-box a sign reading "Loitering Prohibited." The use of the word **loafing** is objectionable, because it does not convey the intended meaning, and it tends to create a hostile spirit. One of the essential requirements in a good watchman is to be able to cultivate friendly, but not familiar, relations with the people who use his crossing daily.

Watchman's Duty in Accident.—The important duties that devolve upon a crossing flagman when an accident occurs are: To protect trains, aid the injured as far as he can, procure full information and communicate it to the foreman as quickly as possible. Even where no apparent injury has resulted, it is necessary that a report be made of all occurrences which might possibly constitute an accident case. It should be especially noted whether or not the headlight was burning, and the engine bell being rung; and what other warning was given by the train. In all circumstances the watchman is prohibited from giving to an injured person or to anyone else, except the Company's officers or claim agents, information which may have any bearing upon the accident, unless he is legally required to do so.

Testing Performance.—Since the failure of a crossing watchman may entail serious results, many observations are made to assure proper performance. Each watchman is tested periodically as to his detailed manner of protecting the crossing which can best be done by a surreptitious visit to the locality. At such times it is noted whether the appliances for flagging or for conveying stop signals are in order. Tests are also made to insure that changing of tours is properly arranged, and that the exact hours of protection are observed. Each watchman is tested at least once every month, and careful record is kept of the tests.

74. Policing the Right of Way

Policing Good Housekeeping.—Policing has been aptly defined by someone as a species of good housekeeping. Just as tidiness is a comfort in the home, so also is good policing a source of satisfaction on the road. An increasing number of through trains are being equipped with observation cars, and it is a common thing to find the vestibule well filled on any pleasant day. Many of the observing travelers are men of affairs whose good opinion is of material advantage to the railroad. The traveler's choice of route for himself is generally an index of the routeing of his goods. Thus a practice that increases the passenger travel is a strong bid for freight business as well.

Importance of Policing.—It has come to be recognized that neatness in the upkeep of a railroad creates quite as marked an impression on the traveler as a high standard in riding. Indeed, the two conditions are interrelated, and policing has long been considered of definite importance on many roads. The extent to which policing is carried out on the trunk lines

Inspecting a Well Policed Road

would of course be out of the question on lines of smaller traffic, but it is believed that even on such lines a certain

amount of dressing up is warranted. Frequently the additional cost of this work is made up in the value of the scrap and usable material recovered. The saving in ballast through a judicious leveling to the standard, both in height within the track and in width of border, is alone an item of consequence.

Leveling and Bordering Ballast.—A high condition of the ballast looks untidy, causes unnecessary expense when surfacing is done, and is a fruitful source of accident both to the traveler and the trackman through trains picking up the stones. Many roads require that the ballast shall be kept below the top of the tie. There is nothing gained by having the shoulder wider than the standard and, aside from its untidy appearance, material is thereby wasted. Even on unimportant branches a neat border is justified. If laid with a board to a regular line it will remain so through at least a year, or until general renewals are made. This applies equally to cinder-ballasted roads; and it will be surprising to find what little cost is involved in maintaining a uniform shoulder along such tracks. The saving in cinder is an important item, because even now there is a deficiency of this material for ballasting purposes.

Ditches and Cross-Drains.—There is a certain amount of policing that is necessary for proper maintenance of the road. The longitudinal ditches must be kept clean for drainage. In doing this work the dirt should not be thrown upon the slopes, because the first rain will wash it back again. Similarly, it should not be deposited upon the ballast border, since additional expense is thereby entailed for cleaning the ballast. In both cases the appearance of the road is rendered unfavorable while the waste is waiting to be loaded by the work train. With a little extra effort the dirt can generally be cast upon the top of the bank and the operation thus ended. If the material must be loaded, it should be done promptly after the initial scraping up. The cleaning of the cross drains and culverts is a further work that must be performed for the maintenance of the railroad, and it should not be neglected for long periods, but should be done frequently. There is no item that impresses the observant traveler so unfavorably as foul drains along the route he is traversing. Much debris

encumbering the water courses suggests to his mind the possibility of a washout with its serious consequences. The thoughtless foreman contributes to an unsafe condition of the road when he throws his old ties into streams above a culvert or bridge.

Mowing Grass and Weeds.—Mowing of the right of way is necessary cleaning which is required once or twice in the season, depending upon the importance of appearances. The burning of grass should never be done upon sodded slopes, and it is preferable that it shall not be done on any sodded ground. It should be forbidden to deposit close to buildings, bridges and tie piles, grass that has been mowed, since when dry it becomes an active source of fires. The monthly cleaning of the bridges, both of the iron work and the decks of highway bridges, is a no less important duty because its omission is not immediately noticeable.

Disposing of New and Old Ties.—In doing the routine work of the section there are numerous small items of tidiness that are often neglected. The ties distributed for renewals can with little labor be piled neatly along the track. Similarly, the old ties taken out of track, which are awaiting inspection by the supervisor or an opportunity for burning, can just as readily be placed at once upon piles, as will eventually be done in any case. It should be stipulated, however, that new ties or old ones shall not be placed in the ditches where they will obstruct the flow of water. When the burning of old ties is in progress, there are apt to be pieces not entirely consumed, which should be disposed of immediately. Care should be taken that the burning is not done upon sodded banks, or along hedges, or under the telegraph line, or close to passing trains. Newly treated ties should not be laid upon the sod, as the oil will destroy the grass in a short time. When new ties are being piled to remain for a considerable period they should not be set directly upon the ground, but should be supported upon two old ties.

Picking Up Scrap.—Scrap material should be collected regularly, sorted, and placed in a bin at the tool house. Old bond wires especially should not be left lying along the track, for thoughtless or vicious persons might throw them upon the telegraph wires and thereby cause interference with

the telegraph service. Small scrap, such as spikes, bolts and nuts, furnish children with a ready means of doing serious damage. Even material that is intended for immediate use should be neatly piled. It is preferable that only moderate amounts of material be distributed where it is in plain view. Unquestionably the ideal condition is that in which no other material is in evidence than what is required for emergency purposes. The impression conveyed to the traveler is that of a finished condition of the road. An excessive quantity of ties, for instance, suggests that the road may have been allowed to deteriorate in this respect; and such is not a reassuring sentiment.

Policing for Safety of Men.—There are certain items that should be given attention for the safety of men and of highway traffic. The ropes at bridge warnings should always be main-

Bridge Warnings Properly Maintained

tained in proper adjustment. Obstructions should be carefully removed to a safe distance from the track, especially where men walk or alight from trains. The crossing and

trespass signs should be placed where they can be seen readily, and care should be had that they continue to face the correct way. These and all other signs should be maintained in an exactly plumb position. It is desirable that the signs follow a uniform standard in design as far as possible.

General Cleaning.—The larger items of general cleaning probably receive due attention practically everywhere. The trackwalker is usually required as he passes to pick up the refuse lodging upon the tracks. The waste paper that is thrown from trains or is blown upon the right of way, which tends greatly to mar the appearance of the road, should be removed promptly. In certain congested sections, mainly those at the approaches to terminals, the matter is of too great a scope for the trackwalker and a special-duty man should be employed whose only work is to gather up this unsightly rubbish. In the summer season the grass that would quickly overrun the ditches and ballast must be pulled up, even though the attention of the whole gang may be periodically required. It is generally recognized that one day each week, preferably Saturday, well may be given over to general cleaning.

Landscape Gardening.—The landscape gardening along the right of way is an item in beautifying that is very agreeable to the passenger. The sodding of slopes or covering them with vines not only is useful in saving labor in ditching, but it adds in a marked degree to the enjoyment of travel. Especially are well laid out and maintained station grounds a pleasant relief to the monotony of a journey. Probably many patrons in their recurring trips watch with anticipation for the view of some slope overgrown with honeysuckle or planted in rose bushes. Where advertising signs would otherwise intrude upon the scene, a row of tall close-growing poplars has been set out along the right-of-way line to hide the signs from view.

Uniformed Track Gangs.—The appearance of the various repair gangs encountered along the road creates an impression upon the tourist. Many section forces take pride in wearing the adopted uniform of blue jeans with a distinctive cap, and such gangs similarly appareled present a favorable appearance. The roads can well afford to foster this senti-

ment even to the extent if necessary of supplying the overclothes at cost. The purchasing department can assist by filling promptly the orders as they are sent in. A neatly uniformed gang will maintain good policing over the section; and the repairs necessary to a safe railroad may be looked for from such forces.

75. Co-operating for Safety in Maintenance

(a) Safety in Distributing Operations

Handling Ties.—In unloading ties from high gondola cars it is necessary first to lift the tie to a position of rest on the top of the side of the car, and then push it over to drop upon the roadbed. Not infrequently mashing of the fingers results from getting them caught between the tie and the top of the car. Men walking along the cars have been struck by a falling tie. If the unloading is being done while the train is moving, there is not only a greater danger of personal accident, but there is a possibility of derailment by the tie catching upon the car and roadbed in such manner as to throw the car over.

Riding on Cars.—Men ought never to ride long distances, or at speed for any distance, upon cars loaded with material. This is especially true of cars with drop bottoms, or cars holding loads that may shift. Although men must work in hopper-bottom cars while ballast is being dragged, the movement should be slow and every precaution for safety observed. Men should not be required or permitted to ride upon loaded air-dump cars while in transit, as they have been known to discharge their load unexpectedly. The practice of riding with the legs hanging over the sides of flat cars, or any other type of equipment, is dangerous.

Obstructing Tracks.—Ties loaded upon flat cars have been jarred off while the work train was running fast and in at least one case caused the wreck of a train moving on an adjacent track. The operation of unloading rails by the derrick or rail loader should be discontinued during the passing of trains on other tracks, as there is danger of the suspended rail being swung about and struck by the moving train. The unloading of any material should not be continued while a train is passing on an adjoining track. Ballast should

never be unloaded so heavily in a service track as to incur the risk of obstructing the movement, but if it does occur, the track must be flagged until the material is safely leveled.

Handling Rails.—A greater number of accidents happen in the handling of rails than in any other single item of M. W. & S. work. If rail forks are provided for releasing rails being unloaded by rail loader or by hand, many such mishaps may be avoided. A capable foreman should always attend the operation of loading or unloading rails, and should direct every move that is made. It is especially hazardous to turn rails by means of a bar entering the bolt holes. The bar is sometimes projected with such force that a man might be pierced through by it. Men need to be cautioned continually to watch that the feet are not caught by rails. Whenever a rail is removed from or added to a loose pile, it is best to inspect carefully to see that all the rails are securely in place.

Handling Frogs and Switches.—The operation of unloading frogs, which often are of the hard center kind and correspondingly heavy, is a live source of danger to the men and should be performed by machines whenever possible. It is seldom that a car load of frogs is distributed along the line, but it is nearly always unloaded for stock in the material yard. In such case a locomotive crane is generally available. The frogs are then sent out one by one, loaded on a flat car or drop-end gondola. They are unloaded in the one case by pushing the frog off the side of the car; in the other, the frog is barred out far enough to let it tilt down, with one end remaining on the car while the other bears upon the track, when the car is pulled away.

(b) Safety in Operation of Hand Cars and Trucks

Safety Rules.—The regulations for employees, in the section relating to track foremen, establish the following rules for the use of hand cars, in which class are included motor cars also, and of hand trucks:

Hand cars or trucks must not be used unless the foreman accompanies them, nor be attached to trains in motion, and must clear regular trains.

The hand car must not be run without at least one man facing in each direction nor without full protection.

Hand trucks when in use must never be so loaded as to prevent prompt removal on the approach of a train, and must al all times be fully protected.

When hand cars or trucks are not in use they must be kept locked and so secured that they cannot be moved to endanger the safety of trains.

Hand cars and trucks must be moved with great caution, with a look-out constantly maintained for extra trains.

The foreman must personally attend to the opening and closing of the switches, and must not permit his switch key to pass out of his possession.

He must caution his men to use great care to avoid injury to themselves and others, and will himself take special care under all conditions to guard against injury to them.

Supplementary Rules.—Rules which are the corollaries of these have been suggested by the experience of men charged with safety matters and are abstracted below:

Track tools must be placed in an orderly and secure manner on the motor or hand car before it is started. Sharp-edged tools must especially be protected against men coming in contact with them.

Motor or hand cars must not be run around curves, where a good view is not afforded, until a flagman has been sent ahead a sufficient distance to protect the movement.

Hand cars and motor cars must be brought under full control at all road crossings. They must always be run through yards and over switches at a safe rate of speed.

The means for conveying stop signs must at all times be at hand ready for instant use.

The foreman must keep a careful watch ahead of the motor or hand car or truck to discover the presence on the rail of torpedoes, the explosion of which is a live source of danger to the men, besides defeating a purpose which may not yet have been served.

Hand cars shall never be run at a greater rate than 10 miles per hour, nor motor cars faster than 15 miles per hour. It is forbidden to start either the hand car or motor car from the side, but this must in all cases if necessary be done from the rear.

Men must never alight in front of a moving car, and it is preferable that they shall wait until the car is stopped before getting off from the sides or rear.

The foreman is required to examine his car frequently to see that it is in fit condition; to watch that the men sitting down do not get their bodies beneath the descending handles; that those standing up keep clear of the handles; and especially that the handles are sound and not liable to break.

Danger in Alighting in Front of a Car

The foreman is forbidden to carry unauthorized persons on his hand car. He is also prohibited from using the hand car for the object of a truck, except in emergencies.

When two or more cars, or a car and truck, are being moved close together, care is required in slowing down or in stopping that they do not collide.

Ample lubrication of the cars must be provided for, both as a labor-saving item and for the proper maintenance of the car.

(c) Safety in Track Repairing

Co-operation of the Men.—When any work is done that breaks the track, the imperative duty is laid upon the foreman to make sure that everything necessary to safe movement has been completed before he restores the track to service. Since failure to observe some obscure defect might be costly, it is also the moral duty of every man of the gang to perform faithfully the part allotted him. This is especially true of spiking and tamping. In rush work it is often necessary for the foreman to assign a definite task to several laborers. Each should feel that he is equally responsible for its correct execution.

Overlooking Necessary Items.—Thus, track is sometimes spiked temporarily only on every other tie; or half the spikes may be removed in advance to facilitate a proposed renewal. If the men were careless it might happen that the ties of one series would remain spiked for one rail, while those of the alternate group were spiked for the other rail. If the track should be used in this condition the rails would spread apart, and an accident surely result. Or, track raising might be in progress either in ordinary maintenance work or in restoring the road after a wreck. If the tamping should be neglected under several ties a rail might break and result in a further accident. The individual members of the gang should assume a personal responsibility in such matters.

Men Working Alone.—Not infrequently it is necessary to delegate to two or three men some special work, such as renewing a pair of splices, or an insulated joint, or re-gaging a section of track, where the supervision of the foreman would necessarily be withdrawn. Each laborer should feel that he is for the moment constituted a foreman in his own right, and take whatever precautions the foreman would take under like circumstances. Only by such co-operation can train accidents be avoided, and the credit of the road for carrying passengers with infallible safety be maintained.

Track Work on Trestles.—A considerable hazard is created by the necessary operation of tightening bolts on trestles. Only the standard wrench should be employed, and care is required to see that it is securely applied to the nut. It

is unsafe to stand on the outside of the track while this item of work is being performed. Also in pulling spikes from the outside of the rails on trestles there is great danger of a man being thrown off if the bar should slip. The spike puller should be used in connection with the claw bar, so that the work can be done while standing within the track. The withdrawal of the spikes should be made easier by striking them a blow with the hammer to loosen their hold upon the wood.

Care in the Use of Bars.—In pulling the spikes along the inside line of the rail many bruised and mashed fingers are received through the bar slipping and in descending catching the fingers upon the top of the other rail. Only a little care is necessary to hold the bar in such manner that the fingers will not be caught. In surfacing with the raising bar a similar mishap might result and also the signal in automatic territory be falsely set by either occurrence, causing detention, or possibly serious accident, to a train. Sometimes when a spike is hard to pull a claw bar is secured under the head of the spike and this bar is then struck a quick sharp blow with another bar. While this practice is permissible, men should be duly warned when it is about to be done.

Separating Men for Safety and Performance.—Many small accidents are caused by men being too closely bunched in a grading, spiking or surfacing operation. This practice also fosters soldiering, and the efficiency of the work suffers in consequence. The careful foreman, as a matter of safety and economy, will so dispose his men that they can work without getting in each other's way, or incurring the risk of being struck by a tool in the hands of another. In such a case the men are also more readily observed to see that they respond promptly to the warning when given to move to a place of safety at the approach of a train. Men ought never to work on main track in a heavy fog, nor on the adjoining track, if the character of the work is such that they would naturally be drawn close to the main track

(d) Safety the First Duty

Safety an Individual Responsibility.—The laborer, equally with the foreman, not only has a duty to himself to avoid

dangerous practices, but he is also obligated to promote as far as he is able the safety of his fellow employee. He should assure himself that the tools he uses are in proper condition, and if they are not, he should take proper action to have them made right. He should never be guilty of doing work by methods that are forbidden, especially since the work can be done better, as well as more safely, by an approved method. He will exercise every precaution to avoid injury to himself and others; he will be alert and watchful and will shun danger; he will be prompt to obey warnings; thus he will set a good example to his less experienced fellow-workers. The watchword of the track forces should be Safety, Neatness, Economy—but **safety first and always.**

INDEX

A

Accessories for work train, 68
Accessories, track, 183
Accident committee, 213
Adverse possession, 27
  loss of title through, 31
Adverse user, 27
Adz, 83
Alfalfa for banks, 62
  soils, 62
  inoculating soil, 63
  rye sown with, 63
Alineing ties, 120
Alternative program, yards, 180
Amount of raise, ballasting, 189
Anchoring rails, 154, 174
Arrangements for connecting up new line, 194
Assessments, 37
Avoiding respacing of ties, 107

B

Ballast, 127
  function of, 127
  sub-ballast, 128
  clean ballast, 129
  supply, 130
  border, 130
  removing, for snow, 131
Ballast border, 130, 225
Ballast cleaning, 90
  depth of cleaning, 90
  raise out of face, 91
Ballast dump cars, 69
Ballast program, 99
Ballasting, machine for, 69
Ballasting without raising, 191
Battered rails on bridges, 175
Bearing face of ties, 117
Bed of cobbles for drainage, 195
Berm ditches, 24, 42
Bermuda grass, 64
Bolts, track, 132
Bolting of rails, 125
Bond wire maintenance, 134
Border for ballast, 130
Boring of rails, 149
  with 24-in. ratchet, 149
  grinding the bits, 149
  with torch, 150
  power drills, 150
Branding of rails, 127
Bridges, tracks on, 173
  depth of ballast, 173
  increased maintenance, 174
  longer ties at ends, 174
  anchoring rails, 174
  battering of ends, 175
  watching fires, 175
  cleaning bridges, 175
  steel guard rails, 176
Buckets for ditching, 68
Buckling of rails, 126
  precautions in ballasting, 190

C

Calcium chloride cars, 73
California privet, 65
Carbon content of rails, 123
Cars for ballast, 69
Causes of accidents, 211
Cause of inferior maintenance, 203
Cause of rail failures, 126

Center-bound track, 91, 156
Center ditches, 129
Cinder ballast inadequate, 189
Cinder filled drains, 54
Clam shell digger, 68
Cleaning ballast, 109
  with screens, 109
  by special method, 109
Crane for loading scrap, 70
Cobbles for drainage, 195
Commissary cars, 73
Cooperation in yards, 180
Correcting grades, 205
Couplers, 212
Creosote process, 115
Cross-drains, 42, 192, 225
Crossings, highway, 111
  special lengths of rail, 111
  hardwood ties for, 111
  drainage, 111
Cross tie renewal, 88, 92
  in yards, 181
Cultivation of roses, 62
Curing water pockets, 38
Curves, adjustment of, 204
Curving rails, 108
  degree requiring, 108
  rule for curvature, 108
Custodians of property, 27
Cutting rails, 148
  making cuts square, 148
  methods for different lengths, 148
  contour and tempering, 149
  with torch, 150
  with rail saw, 150

D

Day in court, 36
Deep excavations, 79
Defects of rails, 126
Degree of maintenance, 164
Density of traffic, 199
Depth of ballast, bridges, 173
Derailments, 213
  on curve, 213
  at switch connection, 213
Detailed surfacing, 163
Deterioration of roads, 202
Digging in ties, 181
Digging out switches, 181
Dirt, disposal of, 77
Disc weeding machine, 71
Ditches kept clean, 225
Ditching, 39
  by work train, 39
  with narrow gage equipment, 40
  by piece work, 40
  by wheelbarrow, 40
  with steam ditchers, 41, 78
Drag line buckets, 68
Dwarf trees, 64
  pines, spruces and willows, 64
  use for snow breaks, 65

E

Economics of rail, 150
  renewals reduced, 151
  speed and superelevation, 152
  effect of low joints, 152
Economics of roadway, 76
Economics of track labor, 207
Economy of large force, 196
Effect of water pockets, 38
Eminent domain, 29
Encroachments, 31
  on company property, 31
  on private property, 31
  means adopted, 34
Ends of bridges, 196
Establishment of full speed, 192
Equipment for ballasting, 190
Expansion openings, 126

F

Farm reaper in mowing, 71
Fences, right of way, 30, 32
  snow, 74

Fill made of gravel, 194
Fires on bridges, 175
First-aid, knowledge of, 218
Flagging trains, 222
Formula for sowing, 60
French drains, 50
  method of placing, 50
  example in fill, 51
  in yards, 54
Frictionless low rail, 151
Frogs and switches, 230

G

Gaging track, 105, 160
  correct gages, 112
Gaging in yards, 184
Gates at crossings, 221
General cleaning, 228
General surfacing, 162
Grade equated, 200
Grades of ties, 117
Gradient problem, 197
Grading methods, 76
  machines, 76
  economy, 79
Grass and weeds, 71
  motor car mowing, 71
  disc weeding, 71
  farm reaper, 71
  weed burner, 71
  weed killer, 71
  oiling to retard growth, 71
Grass, Bermuda, 64

H

Hand cars, 69, 84
Handling rails, 124
Handling ties, 119
Hand trucks, 84
Hardwood ties in crossings, 111
Heart face down, 118
Heating riding car, 67
Highways, relative to, 30
Horse and cart, grading, 76
Honeysuckle, 61
  woodbine, 61
  usefulness, 61
  mowing, 61
Hours at crossings, 219, 222
Hydraulic bender, 110

I

Increased maintenance on bridges, 174
Incidental duties of trackwalker, 215
Individual responsibility, 234
Inoculating soil, 63
Instrumental tests, 96
Insulated joints, 135
  examination of rails, 135
  renewing, 135
Irish heath, 64
Irregular maintenance duties, 207

J

Joints, rail, 124
  types of, 131
  staggering bolts, 132
  maintenance, 134, 153
  insulated, 135

K

Keeping track bolts tight, 110

L

Labor saving methods, 25
Lamplighter in yards, 186
Landscape gardening, 228
Lateral support, 36
Legal protection, 23
Limit of wear of rails, 151
Line and surface, 88, 93
Lining the ends of ties, 120
Lining track, 106
  lining tangents, 159
  lining curves, 160

Locomotive cranes, 113
Longer ties, end of bridges, 174
Loose ties, 155

M

Maintenance surfacing, 158
Manufacture of rails, 122
Marking lines, 32
Mechanical tamper, 112
Monolithic ditches, 42
Monuments, 33
Motor car mowing, 71
Motor cars, 70
Mowing grass and weeds, 71
Mowing honeysuckle, 61

N

Neatness in tie renewals, 121
Need of watching tracks, 214
New and old ties, 119, 226
Night patrolling, 216
Nut locks, 133

O

Obstructing tracks, 229
Oiling the shoulder, 71
Oiling track bolts, 110
Old and new ties, 119, 226
Organization for maintenance, 94, 178
Organization for track raising, 199
Out of face defined, 119

P

Party wall law, 35
Patrolling, 214
Physical features at crossings, 218
Picking up scrap, 70
Pine trees for banks, 64
Pneumatic drill, 110
Policing, 93, 224
  importance of, 224
  for conservation, 185
  for safety, 185, 227
Pony cars, 85
Practice in lining, 164
Precautions in raising, 157
Preliminary investigation, 211
Proceed signals at crossings, 221
Program of work, 25, 96
  tie renewals, 99
  ballast renewals, 99
  rail renewals, 99
  minor items, 100
Progress in repairs, 98
Progress planned in raising, 200
Protection of property, 216
Protection of slopes, 24
Protection of title, 25, 31
Pumping track, 24

R

Rails, 122
  manufacture, 122
  carbon content, 123
  maintenance, 123
  handling, 124, 230
  jointing, 124
  bolting, 125
  spiking, 125
  expansion openings, 126
  buckling, 126
  rail defects, 126
  causes of failures, 126
  branding and stamping, 127
  renewals reduced, 151
Rail renewals, 139
  Main line:
    planning, 139
    shifting the plates, 139
    point of beginning, 140
    tie spacing, 140
    attaching splices, 140
    protection, 140
    quickness essential, 141
    detailed operation, 142
  Branch line:
    practical force, 143
    preparatory work, 143
    protection, 144
    detailed operation, 144

Girder rails replacing Trails:
where required, 144
locomotive crane, 145
the survey, 145
renewing switch connections, 146
tilting ties at step joints, 147
ballast renewals, 147
cutting rails in track, 147
Rail anti-creepers, 137
Rail cutter, 83
Rail layer, 108
Rail program, 99
Rail tongs, 84
Raise out of face, 156
Raising after renewals, 91
Relining tangents, 203
Removing ballast for snow, 131
Renewal of cross ties, 88, 92
in yards, 181
Renewal of frogs and switches, 182
Renewal of splices, 134
Renewal of switch ties, 182
Repairing track, safety rules, 233
Riding on cars, 229
Right of way defined, 27
Rip rap of slopes, 24
Roses for banks, 61
Rugosa, Humilis, Wichuriana, 61
cultivation and propagation, 62
Rotary plows, 73
Routine duties of trackwalker, 215
Rules for cross ties, 121
number of ties, 121
spiking of ties, 122
selection of ties, 122
Rye sown with alfalfa, 64

S

Safety of men, 187
of movement, 187
of hand cars, 230
Scope of roadway work, 23
Screens for ballast, 109
Scrap, collection, 70
Scraper, 76
Seasonable track work, 98
Selection of watchmen, 219
Semi-skilled work, 209
Separating men for safety, 234
Shifting a 2-track line, 201
Shimming track, 165
Side bearing of cars, 212
Signal attendance, 161
Snow and ice, 71
snow plows, 72
spreader cars, 73
snow melting oils, 73
rotary plows, 73
calcium chloride cars, 73
commissary cars, 73
melting snow, 74
snow fences, 74
Sod for banks, 58
top soil, 58
placing, 59
expense of, 59
Source of supply of watchmen, 219
Special duties, 209
Special instructions, 220
Spikes, 133
Spiking of rails, 125
Spilled lading, 186
Splices, 131
Spotting ties, 119
Spruce trees for banks, 64
for snow breaks, 65
Square end rails, 107
Staggering bolts, 132
Stamping of rails, 127
Standard ditching, 77
Standard sections, 89
Steam derricks, 67
Steam ditchers, 41, 78
Storing material, 178
Stripping, depth of, 189
Sub-ballast, 128
Sufficient forces, 208
Supply of ballast, 130
Supply of material, 190
Surfacing in general, 162
in yards, 183

Surfacing out of face, 155
Surveying lines, 33
Switches and frogs, 230
Switches, digging out, 188
Switch repair in yards, 187
Symbols for ties, 116
Systematic work, 96

T

Taking out dips, 157
Tamping low joints, 158
Tamping under ties, 191
Testing watchmen, 223
Tests, efficiency, 106
Tie plates, 133
  rules for use of, 136
  tonnages required, 136
  types on Pennsylvania, 136
  application, 136
Tie rods and spacers, 138
Ties, 115
  renewal of, 104
  treated and untreated, 115
  methods of treating, 115
  object and effect, 116
  symbols, 116
  grades, 117
  bearing face, 117
  heart face down, 118
  piling and handling, 118
  renewal by spotting, 119
  renewals out of face, 119
  old and new ties, 119
  alineing ties, 120
  variations in spacing, 120
  lining the ends, 120
  neatness essential, 121
  rules for number, 121
  rules for spiking, 122
  rules for selection, 122
Tie program, 99
Tie renewals in reballasting, 190
Tie renewals on 2-yr. basis, 191
Tie tongs, 84
Tile drains, 43
  the main drain, 46
  the laterals, 46
  location of drain, 46
  gradient, 47
  joint openings, 47
  drains between tracks, 48
  drains on the Santa Fe, 48
  economy of the drains, 49
Tool grinder, 86
Track bolts, 125
Track gage, 82
Track jack, 81
Track level, 82
Track wrench, 110
Track tanks, 166
  essential provisions, 166
  cross drains, 167
  paving, 167
  thawing ice, 168
  beautifying, 169
Track maintenance, 155
  Main lines:
    surfacing out of face, 155
    loose ties, 155
    keeping bolts tight, 156
    center-bound track, 156
    raise out of face, 156
    precautions in raising, 157
    taking out dips, 157
    maintenance surfacing, 158
    lining tangents, 159
    lining curves, 160
    gaging, 160
    signal attendance, 161
  Branch lines:
    general surfacing, 162
    detailed method, 163
    degree of maintenance, 164
    practice in lining, 164
    shimming track, 165

Track obstruction:
definition, 102
protection, 102
in renewing rail, 103
in renewing ties, 104
in raising track, 105
in gaging track, 105
in lining track, 106
testing, 106
Trackwalkers in yards, 185
Transferring freight, 186
Tunnels, 169
close joints, 169
clearances, 170
work done by night, 170
ventilation, 171
safety rules, 171
watchmen, 172
Typical gravity yard, 177

U

Uniform forces, 208
Uniformed track gangs, 228
Use of bars, 234
Use of shorter rails, 124
Use of tools, 25
Use of tracks in yards, 179

V

Variation in tie spacing, 120
Vegetation, 23
sodding, 57
street dirt, 60
honeysuckle, 61
roses, 61
alfalfa, 62
occasional grasses, 64
dwarf trees, 64

W

Watching for fires, bridges, 175
Watchman's duty in accident, 223
Watchmen tested, 223
Water barrels, 175
Weed burners, 71
Weed killers, 71
Wheels, wear of, 212
Wheelbarrow ditching, 40
grading, 76
Widening fills, 78
Willows for banks, 64
Woodbine for banks, 61
Wooden box drain, 52
Work trains essential, 67
heating the riding car, 67
accessories, 68
buckets for ditching, 68

Y

Yards and terminals, 177
lower degree of maintenance, 177
typical gravity yard, 177
force for maintenance, 178
storing material, 178
utility of work train, 179
use of tracks in yards, 179
alternative program, 180
cooperation essential, 180
digging in ties, 181
renewal of switch ties, 182
renewal of frogs and switches, 182
use of track accessories, 183
lining and surfacing, 183

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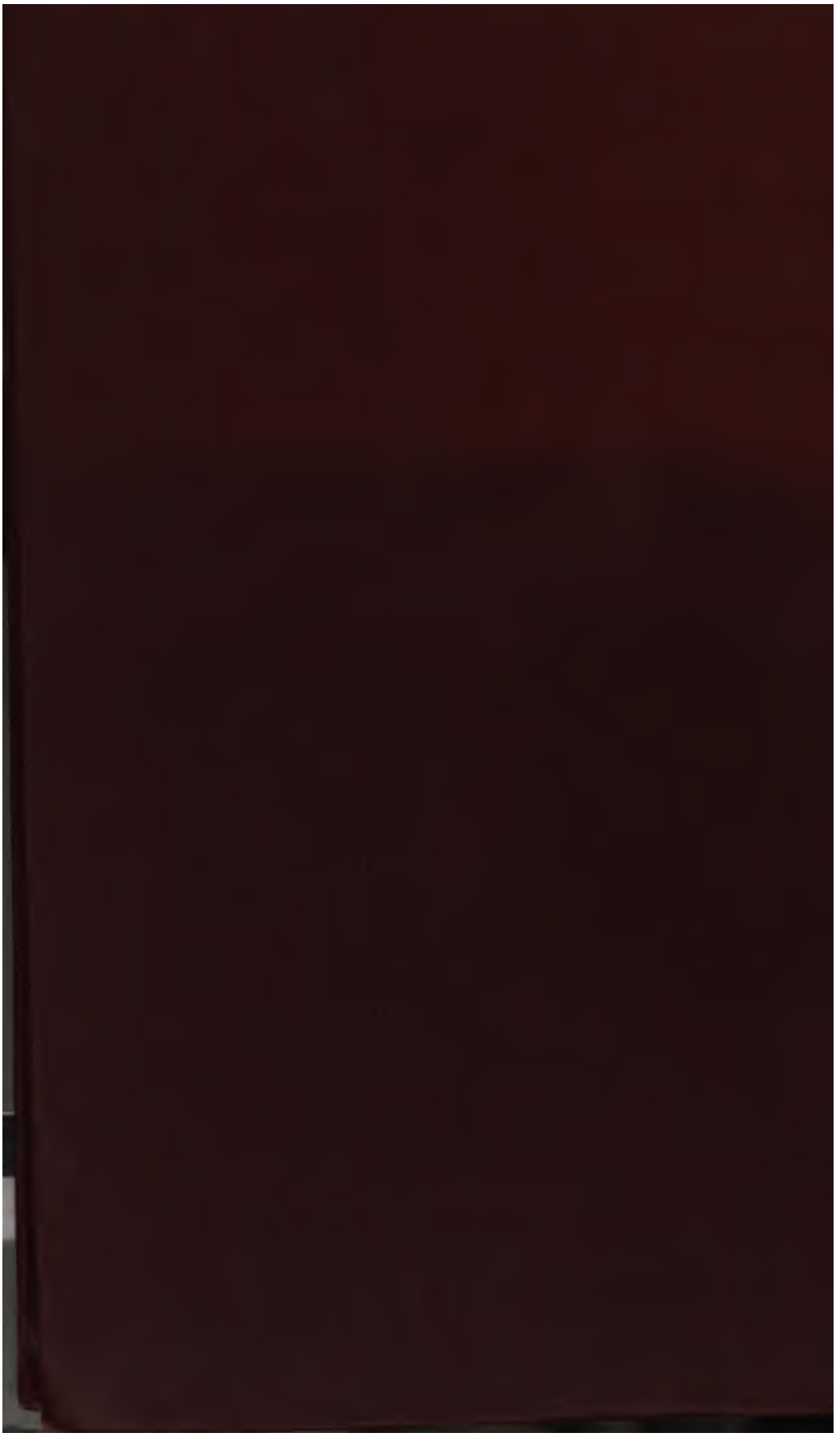
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